ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

THE EFFECT OF ECONOMIC GROWTH AND ENERGY CONSUMPTION ON CARBON DIOXIDE EMISSION IN 14 SELECTED EAST AFRICAN COUNTRIES: EVIDENCE FROM PANEL-ARDL

BY

DEMISSE JARSA

JUNE, 2019

ADDIS ABABA, ETHIOPIA

THE EFFECT OF ECONOMIC GROWTH AND ENERGY CONSUMPTION ON CARBON DIOXIDE EMISSION IN 14 SELECTED EAST AFRICAN COUNTRIES: EVIDENCE FROM PANEL-ARDL

DEMISSE JARSA WOTANGO

A Thesis Submitted to

The Department of Economics

Presented in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Economics (MSc in Resource and Environmental Economics)

Addis Ababa University

Addis Ababa, Ethiopia

June, 2019

Declaration

First, I know plagiarism is to cope and use another's works and claim that it is owns work, which is wrong

Second, this submitted thesis project is my own work and each and every contribution to, and quotation in it from the works of other people has been cited and referenced

Third, I have not permitted, and will not permit, anyone to copy my work with the intention of passing it off as his or her own work

Finally, I acknowledge that copying someone else work or parts of it is wrong, and declare that it is my own work

Signature…………………………………..

Addis Ababa University

School of Graduate Studies

This is to certify that the thesis prepared by DEMISSE JARSA, entitled: The effect of energy consumption and economic growth on carbon dioxide emissions in 14 selected African countries: Evidence from panel-ARDL and submitted in partial fulfillment of the requirements for the degree of Master of Science in resource and economics complies with the regulations of the University and meets the accepted standards with respect to its originality, quality and contribution.

Approval by board of Examiners:

Examiner ______________________________ signature _____________ date ___________

Examiner ______________________________ signature _____________ date ___________

Advisor _______________________________ signature _____________ date ____________

____

Chair of department or graduate program coordinator

Acknowledgment

First of all, I would like to thank the Almighty God being he permitted me for this date and successful completion of this study.

Next, I am deeply indebted to my supervisor Dr. Tekie Alemu for his guidance, suggestions and constructive comments throughout the work. His good treatment gives me the courage to finalize this study and inspiration to be a better academician.

I would like to express wholehearted, deep gratitude to my family(Ayya enjera enate, Etiyye enate, Abba abate, Borra talaku wondimme, Tulla talkua ehitte and tiska taneshu wondime) - it's your effort and dedication to educating me that always strengthen me to pass all those difficult stages and complete my study.

Tamme and Tasfa and all other friends too, deserve my gratitude. I would also like to thank all my classmates for the wonderful time we had together.

Dilla University also deserves great thanks for sponsoring my study for two years at Addis Ababa University.

Table of contents

Contents page number

List of Figures

List of Tables

Abbreviations

ADB	Africa Development Bank
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criteria
AR	Autoregressive
ARDL	Autoregressive Distributed Lags Model
ASEAN	Association of Southeast Asian Nations
BP	British Petroleum’s
BRIC	Brazil, Russia, India and China
CO_2	Carbon Dioxide
D	First Difference Parameter
DF	Dickey-Fuller
DFE	Dynamic Fixed Effects
DOLS	Dynamic Ordinary Least Squares
DRC	Democratic Republic of Congo
D (LCO_2)	First Difference of Log of Carbon Dioxide
D (LTPEC)	First Difference of Log of Total Primary Energy Consumption
D (LRGDPPC)	First Difference of Log of Real Domestic Product Per Capita
D (LPD)	First Difference of Log of Population Density
D (UR)	First Difference of Urbanization
EAC	East African Countries
ECT	Error Correction Term
ECM	Error Correction Model
EIA	Energy Information Administration

EKC	Environmental Kuznets curve
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Squares
GCA	Global Carbon Atlas
GDP	Gross Domestic Product
GHG	Greenhouse Gas
I (0)	Integrated of Order Zero
I (1)	Integrated of Order One
I (2)	Integrated of Order Two
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
IPS	Im, Pesaran and Shin
LCO2	Log of Carbon Dioxide
LM	Lagrangian Multiplier
LPD	Log of Population Density
LRGDPPC	Log of Real Gross Domestic Product Per Capita
LTPEC	Log of Total Primary Energy Consumption
MG	Mean Group
$MTCO_2$	Million Tonnes of Carbon Dioxide
NAFTA	North American Free Trade Agreement
NO_2	Nitric Oxide
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PD	Population Density
PMG	Pooled Mean Group

PP	Phillips Peron
QBtu	Quadrillion British thermal unit
RGDPPC	Real Gross Domestic Product Per Capita
SBIC	Schwarz-Bayesian Information Criteria
SSA	Sub-Saharan Africa
TPEC	Total Primary Energy Consumption
UECM	Unrestricted Error Correction Model
UN	United Nations
UNECA	United Nations Economic Commission for Africa
UNPD	United Nations Population Divisions
UR	Urbanization
US	United States
VAR	Vector Autoregressive
WB	World Bank

Abstract

The study analyzed the effect of economic growth, energy consumption, population density and urbanization on carbon dioxide emission in 14 selected East African countries, with the main interest of the effect of energy consumption and economic growth over the period 1980 to 2016, except for Ethiopia (1981-2016), Tanzania (1988-2016) and Uganda (1982-2016). In doing this, the study used Panel-Autoregressive Distributive Lag (Panel-ARDL), model. Result of panel unit root tests revealed the model variables have a mixed order of integration (or I (0) and I (1)) and none of them I (2). Result of co-integration tests confirmed the existence of long-run co-integrating relationship among the model variables. Pooled mean group estimation result shows all the model explanatory variables were statistically significant in the long-run to explain the variance of carbon dioxide emission for the analyzed countries. The result shows energy consumption, growth in output, population density and urbanization leads to an increase in emission of the gas in the long-run. Energy consumption and economic growth also found significant and have a positive impact in the short-run too, while urbanization found significant and have a negative impact yet it is in a statistical sense. The population density was found insignificant in the short-run. Hence, the study recommended the governments and policymakers in the analyzed countries to develop and implement long-term energy, economic and demographic policies such as switching to cleaner energy alternatives like wind, hydro, biogas, biofuels and solar, green investment in the field of green technologies in order to lower the opportunities of future carbonization of the economic structure, and controlling the rate of population via intervention mechanism like women empowerment, improving girl education as well as creating awareness on negative effect of having a large family size.

Key phrases: energy consumption, economic growth, CO_2 *emission, population density, urbanization, pooled mean group, mean group, dynamic fixed effect, Panel-ARDL*

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

Greenhouse gas, particularly CO_2 emission in the current era is considered to be the most important driver behind increasing global climate change which is one of humanity's greatest challenges these days. Even though its rate of growth has been decreasing recently, its atmospheric concentration continues to increase mainly due to an increase in worldwide energy demand (Poku, 2016; EIA, 2016).

According to EIA (2016), much of increase in demand for energy occurs among non-OECD developing countries largely because of their strong economic growth performance and expanding population.

The same history holds in East Africa since all countries in the region are part of non-OECD. Currently, East Africa is least developed and urbanized, but rapidly developing and urbanizing region in the world (ADB, 2014; UN Habitat, 2014).

Over the past decade, the region made significant growth performance in output by tackling the economic downward spiral that marked the 1980s and much of the 1990s (ADB, 2014). This is observed by the remarkable economic expansion over the period 2012 to 2016 (UNECA, 2018). Over this period, the region's average growth rate was 6.5 % outpacing the average growth rate of African (3.4 %), the world (2.5 %) and even the East Asian (6.1 %).

Recently, the region has been shown substantial progress in terms of demographics, both in urbanization and population too. According to the United Nations Population Division (2018), between 2010 and 2015, the region's urban population has shown remarkable growth with average annual rate of change of 4.55 % which is much higher than Sub-Saharan average (4.14 %) and the African average (3.7 %) and even outpacing the world average (1.9 %). Compared to other regions in Africa continent, East Africa is also most rapidly urbanizing region followed by Central Africa (4.31 %), Western Africa (4.27 %), Southern Africa (2.33 %), and Northern Africa (2.31 %). Further, the region has experienced a significant increase in terms of the total population with an average annual rate of change of 2.71 %, which is much higher than the world average (1.19 %) over the period 2010 to 2015.

Besides economic and demographic growth, the region's energy consumption has also been increased dramatically. According to BP (2018) statistical reviews of world energy, the total primary energy consumption in East Africa has increased from 39.95 million tonnes of oil equivalent in 2012 to 51.05 million tonnes of oil equivalent in 2016, representing a growth rate of 27.78 %. From this, one can understand that energy demand in East Africa has been increasing mainly correlated with the economic and demographic growth performance in the countries of the region.

Even though the demand for energy has been increasing in the region, its present consumption structure is inefficient and pollution dependent, which leads to degradation of the environment. According to UNECA (2014), energy consumption structure in most countries of the region is highly dominated by combustible renewables and waste such as biomass energy source. Out of the total energy consumption in the region, biomass materials such as wood, charcoal, plants and animal wastes contribute well over 80% of the total energy. These energies are not clean and pose a lot to environmental degradation associated with their consumption.

It is well known that an increase in energy and other natural resources used for economic activities causes environmental degradation. High energy consumption causes the high atmospheric concentration of carbon dioxide emission which is the main deriving factor behind rising global temperature and climate change (Kulinois, 2013).

Recently, the growing threat of climate change and global warming has drawn attention on growth- environment debate. It is well known that the countries should undertake their economic activities without harming the natural environment in which economic system by itself relies on. However, in developing economies, it is not possible to grow without polluting the environment due to the fact that the existing production technology and science are not advanced and methods of production technologies are not environmentally friendly. More generally, it is unquestionable that pollution and environmental degradation are quite large mainly correlated with the way the living style of the world's population is constructed, production is undertaken and goods and services are consumed (Ab-Rahim and Xin-Di, 2016).

Thus, environmentalists and economists become more aware of the impacts and consequences of economic activities on the natural environment and shifted the targets of growth from simple conventional economic growth to sustainable and environmentally friendly economic growth (Alam et al, 2016).

A need for sustainable economic growth and environmental quality are desirable policy goals that every economy tries to achieve. However, these policy goals have been perceived to be at odds with each other and create a paradox among nations. The move towards sustainable economic growth requires a strong drive for industrialization, particularly heavy industrialization and result in a more energy-intensive activity. Consequently, energy-related emissions increase substantially. On the other hand, the pursuit of environmental quality is achieved by adopting less energy-intensive industries such as the service sector. However, in the long-term, this may not promote sustainable economic growth, if there is a weak industrial base (Adom, 2016).

The East Africa region falls into this dilemma. Even though the region registered quite impressive growth over the past decades, it is obvious that almost all countries in the region presently exist in the early stage of development, except for Seychelles and Mauritius. Therefore, these countries have to develop and poverty and unemployment in these countries have to be alleviated to help their citizens have a good living standard. In order to grow and develop, these countries have to produce and consume and this process requires the heavy use of inputs, and energy is the main one. On the other hand, given the present inefficient use of energy in the region, the use of this input leads to degradation of the environment which in turn threats the very existence of living in the region. With the present day energy consumption structure, the economic activities in the region result in continuous environmental degradation through CO_2 and thereby result in an unsustainable development situation in the countries in the long-run too.

Therefore, even though the region's contribution to the global atmospheric concentration of CO_2 emissions is smaller in reference to other regions in the world, its contribution to the global atmospheric concentration of anthropogenic CO_2 emissions has been increasing. With the effects of rapid economic, energy consumption, demographics growth on CO_2 emissions and the substantial negative effects of increases in CO_2 emissions, this becomes more worrisome as East Africa has one of the fastest economic, urbanization and population growth rates as well as energy consumption in the world. With one of the fastest economic, energy consumption, population, and urbanization growth rates in the world coupled with present-day inefficient use of energy and pressures on natural resources such as land and forests to meet food, residential and energy demands, it is expected that all other things being equal, its share of global atmospheric concentration of CO_2 emissions over the coming decades will begin to increase although its share of emissions will still be low.

Despite its share of global atmospheric concentration of anthropogenic CO_2 emissions is low compared to other regions in the world, the region faces significant challenges from a change to the global climate and is vulnerable to serious environmental challenges related to a changing climate and largely affected by severely degraded natural resources and the environment in general. This also exacerbated by recurrent droughts, deforestation, agricultural land expansion, and other natural and man-made disasters, results in perpetual poverty and underdevelopment, which in turn accelerates the degradation of natural resources and the environment in general.

Therefore, even though international agreements to limit the factors that accelerate the future climate change will benefit East Africa, the region also has to take important measures to tackle the likely future climate challenges. To this end, knowledge on the major deriving factor behind increasing greenhouse gas, particularly CO_2 emission and their links in East African countries will be a key in designing and implementing proper environmental policies and mitigation strategies aimed at stabilizing greenhouse gas, particularly CO_2 emission in East Africa.

So, this study examines the effects of economic growth and energy consumption and other demographic control variables on CO_2 emission which is the main deriving factor behind increasing global temperature. Its finding has great policy implication for the environment, energy consumption and economic growth of the region.

1.2 Statement of the problem

Following the path-breaking work of Grossman and Krueger (1991), quite a number of studies assessed the link between CO_2 emissions, energy consumption, economic growth, and other control variables. A large proportion of the studies admit that economic growth and energy consumption have played a role in increasing CO_2 emissions globally. These studies have examined for a long time under different circumstances (countries addressed, type of variables used, econometric techniques and time period adopted) and provides different pieces of evidence on the nexus of their model's variables. Therefore, their empirical findings on the link of the variables remained mixed. Such studies can be categorized into three strands.

The first strand of studies considers the environmental implications of the growth process by testing the EKC hypothesis. The EKC hypothesis states that as growth in output in the economy increases, pollutant emissions, particularly CO_2 emissions increase as well until some threshold, and after which it begins to decline with further increase in output (Grossman and Krueger, 1991). Hamilton and Turton (2000), Endeg (2015), Adu et al (2017), Özokcu and Özdemir (2017) are some of the studies in this line.

The second strand of studies targets on the relationship between energy consumption and output growth. This nexus indicates that the pursuit of economic growth needs more energy consumption and more efficient energy use requires a higher level of income growth. Since the initial work of Kraft and Kraft (1978), Granger causality testing mechanism has become a major tool for investigating the nexus between growth in output and energy consumption in different countries. Jumbe (2004), Asafu-Adjaye (2000), Saidi and Sami (2014), Aqeel and Butt (2001) and Huang et al (2008) are some of the studies in this line.

The third strand of the studies focuses on the examination of the dynamic links between environmental pollutants, particularly CO_2 emissions, growth in output, energy consumption and other important control variables altogether. Apergis and James (2010), Wang et al (2011), Acaravci and Ozturk (2010), Endeg et al (2016), Ozturk and Acaravci (2010), Esso and Keho (2016), Zakarya et al (2015), Pao and Tsai (2011), Oh and Bhuyan (2018), Hassan and Nosheen (2018), Mohmood and Chaudhary (2012), Saboori and Sulaiman (2013), Tang and Tan (2015), Rahman and Kashem (2017) Halicioglu (2009), Poku (2016), Hilaire and Fotion (2015), and Shimalis (2017) are some of the studies in this strand.

Using panel-ARDL approach, Asongu et al (2015) for 24 selected African countries found a significant positive relationship between energy consumption, economic growth, and CO_2 emissions. The results also confirmed by Rasman and Kashem (2017) for Bangladesh and Saboori and Sulaiman (2013) for a sample of selected Association of Southeast Asian Nations (ASEAN) countries, and Zakarya et al (2015) and Pao and Tsai (2011) for BRICS countries. Using the same econometric methodology (Panel-ARDL), Poku (2016) for Sub-Saharan African countries found a significantly positive population and urbanization on carbon dioxide emissions.

In view of the above statements, this study intends to investigate the relationship between energy consumption, economic growth and CO_2 emissions in 14 selected East African countries by adding the two most responsible demographic variables such as population density and urbanization into the nexus. Although studies on this area have been done on a number of countries in both developed and developing countries, to the best of researcher knowledge, there is no major panel studies that investigate the interactions between energy consumption, economic growth, CO_2 emissions including some other demographic variables such as population density and urbanization exclusively in East Africa. Therefore, this study contributes to the existing literature and ongoing debate on climate change by examining the effect of energy consumption, economic growth, population density and urbanization on CO_2 emissions in 14 selected East African countries.

The examination uses newly developed heterogeneous panel co-integration technique which is Panel Autoregressive Distributive Lags (Panel-ARDL) and which has rarely been used. To researcher knowledge, the Panel-ARDL methodology has never been employed to examine climate change related issues in East Africa, even Africa in general, except Asongu et al (2015) for the case of 24 African countries and Poku (2016) for Sub-Saharan African (SSA) countries. But this study differs from their work in three important cases. First, unlike Asongu et al (2015) and Poku (2016), this study considered the issue of spatial correlation of the error terms across cross-section through demeaning the data following the recommendation of Pesaran et al (1997; 1999). Second, unlike Asongu et al (2015) and Poku (2016), investigation in this study used unbalanced panel data which is more common in the country-level study. Third, whereas Asongu et al (2015) and Poku (2016) checked the long-run relationship between the model variables using only Pedroni (1999; 2004) which has less power when the model variables are once fractionally integrated, this study used three co-integration tests procedure in order to check the consistency of the result across tests.

1.3 The objective of the study

The general objective is to examine the effect of energy consumption and economic growth on carbon dioxide emission in 14 selected East African countries. Under this, the specific objectives are: -

- ✓ To investigate the effect of energy consumption on CO_2 emissions in 14 selected East African countries.
- ✓ To investigate the effect of economic growth on CO_2 emissions in 14 selected East African countries.
- ✓ To examine the effect of population density on CO_2 emissions in 14 selected East African countries.
- ✓ To examine the effect of urbanization on CO_2 emissions in 14 selected East African countries.

1.4 The hypothesis of the study

- ✓ Energy consumption positively and significantly affects CO_2 emissions in both short and long-run.
- ✓ Economic growth positively and significantly affects CO_2 emissions in both short and long-run.
- ✓ .Population density positively and significantly affects CO_2 emissions in both short and long-run.
- ✓ Urbanization positively and significantly affects CO_2 emissions in both short and long-run.

1.5 Significance of the study

In recent years, economic growth performance in the East Africa region has been impressive. This has inspired political leaders and policymakers to set ambitious economic development goals, with some countries explicitly aiming to become middle-income nations around the late 2020s. It is unquestionable that, the region's development effort, as well as the ever-increasing population, actually requires increased energy consumption since it plays a major role in providing the foundation for economic activity and human well-being. However, energy consumption also acts as the driving force for environmental degradation and greenhouse gas (GHG) emission, particularly CO_2 emissions.

Given this, it is important to have this study which investigates the implications of energy consumption, overall economic growth, population density as well as urbanization on CO_2 emissions. Examining and identifying the link between energy consumption, carbon dioxide emission, economic growth, population, and urbanization will provide information to the policymakers to enable them to come up with the appropriate policies towards the region's sustainable development effort. In line with this, the findings of this study have significant policy implications for the energy sector, environmental protection, and agricultural sector and for anyone further concern on economic growth in East Africa region. Identifying the direction of the relationship of the variables will provide information for further study and policy actions of the region.

1.6 Structure of the study

The rest of the paper is structured as follows. Chapter two discusses the existing theoretical and empirical literature. The descriptive study: the data, historical trends and descriptive statistics of the model variables are covered in chapter three. Chapter four discusses the description of the model variables and methodology of the study. The empirical analysis, presentation of results and discussion of findings are covered in chapter five. Chapter six is entirely devoted to conclusions and recommendations.

CHAPTER TWO

REVIEW OF THE THEORETICAL AND EMPIRICAL LITERATURE

2.1 Theoretical Literature

2.1.1 Economic growth and the natural environment

The environment-economy relationship is very complex, dynamic and all-embarrassing. The economic system, which is part of the natural environment, is largely interlinked with the natural environment and both of them affect each other. Every economic activity can have significant impacts on the natural environment and also every environmental change can also have an important implication on the economic system. The natural environment is central to economic activity and growth by providing directly the resources (energy or material) that are required as inputs for the production of goods and services and indirectly absorbing and processing unwanted by-products in the form of pollution and waste, managing flood risks, life support service and amenity, educational and spiritual values. In turn, the economic system affects the natural environment through the insertion into and extraction from the environment (Henley et al, 1997).

The natural environment is central to the economic system. The process of economic activity is largely influenced by the natural environment, and the environment, in turn, is affected by the extraction of natural resources and generation of waste by-products from economic activity.

While growing economic activity has provided a number of benefits, enhancing the standard of living and improving quality of life across the world, it has also generated larger quantities of waste by-products and results in depletion of natural resources thereby the degradation of the natural environment. Given this, the question of sustaining the economic growth without degrading the natural environment has begun to attract public attention both in developed and developing countries (Everett et al, 2010).

For one point of view, economic growth requires more energy and material inputs from the natural environment which in turn generates a larger amount of waste by-products including the atmospheric concentration of greenhouse gases to the environment. The atmospheric accumulation of greenhouse gas due to continuous extraction of natural resources from the environment could result in the degradation of the natural environment thereby decline in human welfare, despite growth in the economy. When the accumulation of pollutants run beyond the carrying capacity of the natural environment the whole economic system will fall at risk (Daly, 1977 cited in Panayotou, 2003).

The accumulation of pollutant and degradation of the environment which is evident from the increased insertion in to and extraction of natural resources from the environment affect the general system of the environment which manifests the change in the form of changing the climate- which is mostly mentioned as the problem of global climate change.

On the other extreme, there is an argument that states environmental improvement and advancement in economy go hand in hand implying the increase in environmental quality goes along with advancement of the economy due to the fact that higher incomes increased demand for less material intensive goods and services as well as demand for improved environmental quality that leads to the adoption of environmental protection measures (Panayotou, 2003 cited in Endeg, 2015).

Contrasting the view that environmental improvement moves along the economic growth, the other scholars hypothesize an inverted- U relationship between environmental degradation and economic growth. The relationship between economic growth and environmental degradation could vary along the countries growth path, and not follow a fixed path implying it may change the sign from positive to negative. Such hypothesized Inverted-U relationship between environmental degradation and economic growth came to be known as the Environmental Kuznets Curve (EKC) hypothesis (Panayotou, 2003). The EKC concept first emerged in 1991 with initial works of Grossman and Krueger whose studies suggests that the environmental impact indicators are an inverted U shaped function of economic growth.

The Environmental Kuznets Curve (EKC) is often used to describe the relationship between economic growth and environmental quality. It refers to the hypothesis of an inverted U-shaped relationship between economic growth and some measures of environmental quality. The hypothesized relationship between various indicators of the environmental degradation and income per capita infers that at early stages of economic growth, environmental degradation and pollution increases but beyond some level of growth the trend will reverse so that at high-income levels, economic growth leads to environmental improvement (Everett et al, 2010).

According to Everett et, al, such Inverted-U relationship between economic growth and environmental indicators could be explained under different circumstances. First, at a lower income level, individuals use their limited income to satisfy their basic consumption needs rather than pollution abatement. But once a certain level of income is achieved, individuals begin considering the trade-off between environmental quality and consumption, and environmental damage increases at a lower rate; and after a certain point, spending on abatement dominates as individuals prefer improvements in environmental quality over further consumption, and environmental quality begins to improve alongside economic growth. Second, initially firms devote all of their effort on the expansion of their gross product as quickly as possible, but as technology evolves production processes become cleaner and more resource efficient, indicating technology progress effect. Third, the development pattern of any economy is characterized by the changing structure of economic activity, indicating Lewis growth model. In stage one, any economic activity is largely depending on the primary production sector such as extraction of natural resources and agriculture which likely increase the level of environmental pollution. Under stage two resources are moved from the primary sector to the secondary sector like manufacturing since basic needs are satisfied and further consumption is concentrated on consumption good. Further, in stage three society moves from the secondary to the tertiary sector such as services which is characterized by much lower levels of pollution.

Generally, the theoretical explanations of the EKC hypothesis are based on three main effects. First, the scale effect: showing a positive relationship between economic growth and environmental degradation and every increase in economic activity leads to pressure on the environment. An increase in the production process requires the consumption of more energy inputs and in turn emits more emissions and waste by-products. Therefore, economic growth has a negative effect on the environment, where increased production and consumption causes increased environmental damage. Such a proportional increase in the pollution and other environmental wastes from the pure growth in the scale of the economy is due to the inability of the economy to change in the structure and technology. Second, the composition/structure effect: the contribution of different sectors in a gross domestic product affects the environmental degradation intensity caused by economic growth. This implies, the composition of production changes along the growth path initially economic growth leads to industrialization and as the goods balance shifts from agriculture to manufactured products, environmental damage increases but the balance then shifts from producing manufactured goods to producing services, due to both demand- and supply-side changes, reducing the level of domestic environmental damage. Finally, technology effect: technological developments lead to a change in the environmental impacts of production. This implies, when an economy reaches a certain level of wealth, it invests a portion of its wealth to research and development activity towards environmentally friendly production technology (Everett et al, 2010).

However, the Environmental Kuznets curve (EKC) hypothesis is questionable to policy-making from many grounds, particularly from its theoretical inadequacy. First, EKC analyses are based on a limited set of environmental pollutants and the conclusion derived from these analyses are not applicable for all type of environmental pollutants. Second, the econometric evidence put forward in support of the EKC has been found to be less reliable and robust than previously thought implying the choice of model used to describe the relationship between income and pollution has a significant impact on the results of the analysis. Third, the assumption of exogenously given income seems unrealistic. The environment and the level of income (economic growth) may exhibit bidirectional causality, meaning that environmental degradation can have a feedback impact on economic growth in different ways and hence can affect the income level. Fourth, due to the strong environmental regulation in the developed counties, industries with higher environmental pollution may migrate to developing countries. This may result in a decline in developed countries pollution and the increase in developing countries. Fifth, aggregate pollution might not be declining in developed countries as it is being observed that as some wastes like sulfur and nitrous oxide decline, others like CO2 and solid wastes increase. Finally, due to an informal regulation in developing countries, availability of better information now than ever, trade liberalization which can bring more efficient and environmentally friendly production, the environmental improvement expected from developed nations might also be possible in developing ones and good environment might be possible before the assumed higher income level (Stern, 2003; Everett et al, 2010).

2.1.2 Energy and Economic growth

Energy is a major determinant of economic growth. It enhances economic growth and development of an economy. All the activities within an economy in terms of production, distribution, and consumption of goods and services require energy as its input (Raheem and Yusuf, 2015). It plays an important role in the economic development of a country by enhancing the productivity of other factors of production. Therefore, "*Energy is the lifeblood of any modern economy"* (Kulinois, 2013 pp, 1).

Access to energy is a key for human wellbeing, economic development, and poverty as well as unemployment alleviation and hence energy and economic development are strongly connected. The level and status of secure energy supply are largely depending on the level of economic advancement and vice versa. Therefore, a high level of economic development leads to a high level of energy demand as well as supply and in turn a high level of energy use results to a high level of economic development (Omari, 2013).

Since the works of Kraft and Kraft (1978), an issue of the causal relationship between energy consumption and economic growth is at the heart of the energy economics literature. At the heart of this issue, a number of studies investigated the causation between energy consumption and economic growth by raising the question as to which variable takes precedence over the other, implying does energy consumption causes economic growth or does economic growth cause energy consumption? However, they are remained empirically controversial and elusive or found diverse results due to the different data set, alternative econometric methodologies and different countries' characteristics (Ozturk, 2010).

According to Ozturk (2010), though not conclusive, the results of the studies on the direction of a causal relationship between energy consumption and economic growth are grouped into four types of hypothesis.

1. Neutrality hypothesis: indicates that energy is neutral for growth. There is no causality between economic growth and energy consumption implying neither the expansionary nor contractionary policies in relation to energy consumption will have any effect on economic growth and vice versa. According to this hypothesis, energy conservation policy has no significant effect on the overall level of economic growth.

2. Feedback hypothesis: contradicting the point of neutrality hypothesis, this hypothesis infers that there is a bidirectional relationship between energy consumption and economic growth showing both energy consumption and economic growth are mutually interdependent and hence jointly determined. According to this hypothesis, both economic growth and energy consumption act as a complement to each other, and hence an increase in energy consumption results in an increase in economic growth and vice versa. In this case, it is important to consider the impact of possible negative effects on economic growth in establishing energy conservation policies.
3. Conservation hypothesis: indicates there is unidirectional causality running from economic growth to energy consumption. This hypothesis is supported by economists who consider energy as intermediate goods. According to this hypothesis, an increase in economic growth causes an increase in energy consumption and further production of energy. Therefore, this hypothesis recommends the energy conservation policy could be implemented without the impacts on economic growth.
4. Growth hypothesis: indicate there is unidirectional causality running from energy consumption to economic growth. According to this hypothesis, energy is a limiting factor to economic growth. An increase in energy consumption due to expansive policy contributes to the growth of the economy while a decrease in energy use due to conservative policy adversely affects economic growth. Therefore, the policies targeted on energy conservation may have significant impacts on economic growth.

2.1.3 Energy and the natural environment

Access to affordable and secure energy is essential for economic prosperity. Energy provides heat and light for homes, fuel for transportation and power for industries (BP, 2015). Therefore, it is unquestionable that energy is fundamental to every economic activity and also its sufficient supply is prerequisite for every fast-growing economy. The expansion of production by growing economy requires the consumption of more energy and hence limited availability of energy critically impairs socio-economic development of a nation (Omari, 2013)

Despite modern energy access in terms of its production and consumption is a vital determinant of the growth and development of any modern economy, the sector is highly criticized from the environmental grounds and has negative environmental implications.

Energy affects environmental quality through deforestation associated with unsustainable biomass energy dependence, emission from burning fossil fuels (oil, gas, and coal) which are considered as the major source of accumulation of greenhouse gas to the atmosphere. The increased accumulation of greenhouse gas, especially carbon dioxide (CO_2) in the atmosphere due to continuous extraction and use of such fuels could result in the degradation of the natural environment thereby climatic change (BP, 2015).

Though plentiful and currently more affordable than other energy resources, fossil fuels emit carbon dioxide (CO_2) and other greenhouse gases through their production and use in homes, industry, and vehicles. According to BP sustainability report, out of total energy consumption (billion tons of oil equivalent) around 32 % comes from oil, 30 % from coal, and 24 % from gas and totally 86 % energy consumed comes from fossil fuels. However, the remaining 14% comes from renewable energy sources i.e. hydroelectricity (7 %), nuclear (4 %) and other renewables (3 %).

Given this, energy consumption is the major contributing factor to the accumulation of greenhouse gas in the atmosphere which is responsible for global climate change.

Global warming and climate change are disasters that human beings have had to cope with for a number of years. Across the world, human beings are experiencing the significant impacts of climate change which is evident from increasing earth surface temperature, melting ice caps, rising sea levels, changing precipitation patterns, decreasing freshwater supplies, worsening the agricultural productivity and wildlife and reducing the productivity of labor force (Alam et al, 2016).

Today's global climate condition is largely affected by an excessive concentration of greenhouse gas in the atmosphere for the past century. Among the various greenhouse gases which cause global climate change, co2 is not the most abundant. However, its excess can be directly related to human activities such as extraction of resource for production, cement production, clearing of forests and other resources for energy use and other land use purposes (Özokcu and Özdemir, 2017).

Given this, transforming the energy sector to alternative sources which are clean and environmental friendly is a burning issue. International environmental institutions like Intergovernmental Panel for climate change (IPCC) and different other governmental and non-governmental organizations propose the need to shift to alternative environmental friendly energy sources such as renewable energy sources.

2.2 Review of the empirical literature

The nexus between energy consumption-economic growth-environmental pollutants has been the area of intense research over the past few decades. A number of studies have investigated the nexus between energy consumption, carbon dioxide emissions and economic growth exclusively and also by including different variables of interest since the path-breaking work of Grossman and Krueger (1991). However, depending upon the econometric techniques adopted, underlying variables used, the development stages of the countries studied and the time period used in the analysis, the evidence of the studies remain controversial to date. These studies which carried out under different circumstances (countries addressed, type of variables used, econometric techniques adopted and time period of the study) and infers different pieces of evidence can be categorized into three groups. These are: first, studies that analyzed the environmental implication of economic growth via testing the validity of the Environmental Kuznets curve (EKC) hypothesis. Second, studies that analyzed the nexus between energy consumption and economic growth via Granger causality tests. Third, the studies that investigated the three-way linkage between energy consumption, economic growth and carbon dioxide emissions by adding a number of control variables into the modeling framework.

2.2.1 Studies in the first strand of literature

The first group largely focuses on the nexus between economic growth and environmental pollutants which are mainly focused to test the validity of the EKC hypothesis which claims an inverted-U shaped relationship between economic growth and measured the environmental pollutants. Grossman and Krueger (1991), Hamilton and Turton (2002), Endeg (2015), Adu, et al (2017), Joseph (2010) and Özokcu and Özdemir(2017) are some of the studies fall in this strand.

Using the global entrepreneurship dataset, Grossman and Krueger (1991) investigate the EKC hypothesis for the case of North American countries, particularly for Mexico. Taking different environmental indicators(mostly ambient pollutions), and controlling for various factors affecting the environment, they assessed the potential environmental impacts of the free trade agreement in North America (NAFTA) and analytically proved an inverted U- shaped EKC hypothesis. The assessment found that environmental pollution level increase as a country's per capita income grows and begin to decline once a country's per capita income reached a turning points ($4000 to $5000) that marginal increment in a country's per capita income should become a push factor for increased political pressure for environmental protection and perhaps a change in individuals consumption behavior.

A study by Hamilton and Turton (2002) examined the determinants of emission growth in OECD countries over the period 1982-1997 using decomposition analysis approach. The results confirmed the existence of an Inverted-U shaped environmental Kuznets curve. The result further reveals economic growth is the main driving factor that positively affects emission growth in the short run in OECD countries. However, in the long-run, emission growth is offset by a fall in energy intensity because of improved technology achievable through economic growth.

Moreover, Endeg (2015) researched the relationship between economic growth and environmental degradation in Ethiopia between 1969/70 to 2010/11 applying Johansen co-integration approach. The empirical results found evidence for the presence of EKC in Ethiopia, indicating environmental degradation increase with per capita income growth during the early stage of the economy, and then decline with per capita income growth after arriving at a certain threshold. According to Endeg, early-stage environmental degradation is associated with the nature of the economy. At the initial stage, all economy is agrarian and largely depends on nature for resources as well as input use. However, with the introduction of environmentally friendly policies and an increase in the share of the service sector in the country's economy which is least dependent on nature, environmental degradation declines in the future.

Furthermore, Adu, et al (2017) studied the relationship between economic growth and environmental pollution in selected West African countries over the period 1970-2013. The empirical study used time series of cross-section (multiple countries panel datasets) and general econometric model. In empirical modeling, they incorporated carbon dioxide emission and combustible renewable waste as environmental pollution indicators. The study found a significant positive relationship between economic growth and environmental pollution indicators in the short run, but not in the long run, indicating the non- existence of an inverted U-shaped curve. The study result contradicts the earlier studies carried out by Endeg (2015), Hamilton and Turton (2002), and Grossman and Krueger (1991).

Özokcu and Özdemir (2017) considered 26 OCED countries and 52 emerging countries in investigating the environmental Kuznets curve hypothesis using a standard panel estimation model covering the period 1980-2010. Özokcu and Özdemir found evidence of an Inverted-N shaped relationship between environmental degradation and economic growth, suggesting the environmental Kuznets curves do not hold. Thus, economic growth cannot be a remedy for environmental degradation.

Joseph (2010) investigated the relationship between economic growth and carbon dioxide emission in Ghana, Nigeria, and Sierra Leone over the period 1970-2006 using panel estimation. The study used the fixed effect modeling and found that an Inverted-U shaped curve hypothesis (EKC) does not hold in West Africa. The study results suggest that these countries should take policy action to ensure efficiency in energy consumption and reduction in carbon dioxide emissions.

2.2.2 Studies in the second strand of literature

The second strand of the research targets to the nexus between energy consumption and economic growth. This nexus infers that economic growth and energy consumption are closely related and also be jointly determined implying more efficient use of energy largely depends on the high level of economic growth and also higher economic growth needs more energy consumption. Since the pioneering work of Kraft and Kraft (1978), the causality relationship between energy consumption and economic growth is intensively discussed and debated and provides a number of empirical works into the literature which presents inconclusive evidence.

Jumbe (2004), Asafu-Adjaye (2000) Saidi and Sami (2014), Aqeel and Butt (2001) and Huang et al (2008) are some of the studies in this strand.

Jumbe (2004) examined the co-integration and causality between electricity consumption (KWh) and overall economic growth (GDP), agricultural GDP and non-agricultural GDP, respectively in Malawi over the period 1970-1999 using Granger causality and error correction techniques. The results showed that co-integration is established among electricity consumption, overall GDP and non- agricultural GDP, but not with agricultural GDP. The Granger test found a bi-directional causality between electricity consumption and overall GDP implying that overall GDP and electricity consumption are jointly determined, and also found unidirectional causality running from non- agricultural GDP to electricity consumption. The error correction model (ECM) showed one- way causality running from overall GDP and non- agricultural GDP to electricity consumption showing that continuous growth in overall GDP may result in continuous growth in electricity consumption.

Moreover, Asafu-Adjaye (2000) studied the causal relationship between energy consumption and economic growth in four Asian countries, namely:- India, Indonesia, the Philippines and Thailand using co-integration and error correction modeling techniques. The empirical result found unidirectional causality running from energy consumption to economic growth for India and Indonesia, and a bidirectional causal relationship between energy consumption and economic growth for Thailand and the Philippines in the short-run. However, the result found unidirectional causality running from energy consumption and energy price to economic growth in the long-run. The study further found that energy consumption, economic growth, and energy price are mutually causal in the case of Thailand and the Philippines. Except for Indonesia and India where neutrality is observed in the short-run, the study proved that the view that energy consumption and economic growth are neutral with respect to each other does not hold.

In a related study, Saidi and Sami (2014) assessed the two- way relationship between energy consumption and economic growth in Tunisia between 1974 -2011. The assessment employed Johansson co-integration technique and found a bidirectional causal relationship between energy consumption and economic growth in the long-run. The study result implies that energy use is a determinant factor for economic growth and hence a high level of energy use results to a high level of economic growth and vice versa, which contradicts the new- classical assumption of the neutrality of the effects of energy on economic growth

Using Hsiao's version of Granger causality that provides more robust result over arbitrary lag length selection and technique of co-integration, Aqeel and Butt (2001) researched the causal relationship between energy consumption and economic growth as well as between energy consumption and employment for Pakistan. Both co-integration and Granger causality test result found that economic growth does Granger cause total energy consumption and energy consumption causes employment. The result from independent analysis for disaggregated energy consumption found unidirectional causality running from economic growth to petroleum consumption, electricity consumption to economic growth. However, in the case of the gas sector, the result indicates no causality among economic growth and gas consumption.

Furthermore, Huang et al (2008) investigated the causal relationships between energy use and economic growth using evidence from 82 countries over the period 1972 -2002. They analyze the data by dividing the countries into four groups: low-income group, lower middle-income group, upper-middle-income group, and high-income group. The investigation used a dynamic panel data approach and found no causality between economic growth and energy consumption in the low-income group. The result further found economic growth results in energy consumption to rise in middle-income groups (both lower and upper-middle-income group), but in the high-income group, economic growth results in decline energy consumption.

2.2.3 Studies in the third strand of literature

The synthesis of the above two kinds of literature has created a relatively recent and emerging research area that analyzes both nexus into the same framework. This third strand concentrates on the assessment of the dynamic relationships between economic growth, energy consumption and environmental pollutants altogether. Apergis and James (2010), Wang et al (2011), Acaravci and Ozturk (2010), Endeg et al (2016), Ozturk and Acaravci (2010), Esso and Keho (2016), Zakarya et al (2015), Pao and Tsai (2011), Oh and Bhuyan (2018), Hassan and Nosheen (2018), Mohamood and Chaudhary (2012), Saboori and Sulaiman (2013), Tang and Tan (2015), Rahman and Kashem (2017) Halicioglu (2009), Poku (2016), Hilaire and Fotion (2015), and Shimalis (2017) are some of the studies in this strand.

Apergis and James (2010) analyzed the three-way linkage between energy consumption, economic growth and CO_2 emissions in 11 countries of the Commonwealth of independent states using a panel vector error correction model over the period 1992-2004. The econometric analysis on the panel data of 11 countries confirmed that energy consumption positively and significantly affects CO_2 emission in the long-run, and hence a more intense use of energy results to an increase in CO_2 emission. The result further found economic growth impact follows an inverted-U shaped curve (EKC) hypothesis. The Granger test found bidirectional causality among energy consumption and CO_2 emission. Further, in the short-run, the result found a unidirectional causality runs from economic growth and energy consumption, respectively to CO_2 emissions, and bidirectional causality among energy consumption and economic growth.

Zakarya et al (2015) studied the relationship between the total energy consumption, foreign direct investment, economic growth, CO_2 emission in the BRICKS countries during the period 1990-2012 using Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and panel Granger causality testing methods. The study found a significant long-run co-integrating relationship between CO_2 emissions and independent variables such as energy consumption, economic growth foreign direct investment. The results of the FMOLS and DOLS methods show that energy consumption, economic growth, and foreign direct investment significantly increase the CO_2 emission in the long-run. The Granger test found unidirectional causation running from CO_2 emissions to energy consumption, economic growth, and foreign direct investment.

Using evidence from the same sample countries (BRICS) and econometric methodologies (panel co-integration techniques and Granger test), Pao and Tsai (2011) assessed the impact of economic growth and financial development on environmental degradation over the period 1980 to 2007, except for Russia (1992-2007). The study found carbon emission is energy elastic but foreign direct investment inelastic and also confirmed the existence of the EKC for the analyzed countries. The Granger test found highly significant bidirectional causality between emission and foreign direct investment, economic growth and emission, and economic growth and energy consumption, respectively. Moreover, the Granger test reveals unidirectional causality runs from economic growth to foreign direct investment and energy consumption to emissions.

Using similar panel-co-integration and Granger causality, Wang et al (2011) researched the three-way relationship between energy consumption, economic growth and CO_2 emission using evidence from 28 provinces in China over the period 1995-2007. The research found a long-run relationship between the variables. The result further found bidirectional causality among economic growth and energy consumption and also CO_2 emissions and energy consumption. The result also suggests CO_2 emission and energy consumption can affect each other in the long run, indicating CO_2 emission causes energy consumption and vice versa. Furthermore, the result found economic growth cause of both CO_2 emission and energy consumption in the long run.

Tang and Tan (2015) assessed the relationship between CO_2 emission, energy consumption, FDI and economic growth in Vietnam during the period 1976-2009. The study used co-integration and Granger causality approach and found evidence of long-run co-integrating relationship among the variables. The study also confirmed the existence of the EKC for Vietnam. Tang and Tan further found that energy consumption and economic growth significantly and positively affects the level of CO_2 emission of the country. Furthermore, the Granger test found energy consumption Granger causes the level of CO_2 emission in Vietnam in both the short and long-run.

Moreover, by using the same econometric approaches, Rahman and Kashem (2017) evaluated the relationship between carbon emissions, energy consumption and industrial production in Bangladesh during the period 1972-2011. The empirical results found that there is a long-run co-integrating relationship between the variables. The result further reveals that the country's industrial production and energy consumption have a statistically significant positive impact on the level of carbon emissions both in the short and long-run. However, the Granger test found unidirectional causation running from both energy consumption and industrial production to carbon emission in both the short and long-run, indicating that both energy consumption and industrial production determines carbon emission.

In the third strand of literature, quite a number of studies used Autoregressive Distributed Lags (ARDL) technique of co-integration to investigate the three-way linkage between energy consumption, economic growth, and environmental indicators by including different control variables in their model. Hilaire and Fotio (2015), Oh and Bhuyan (2018), Hassan and Nosheen

(2018), Mahmood and Chaudhary (2012), Saboori and Sulaiman (2013), Halicioglu (2009), Ozturk and Acaravci (2010), Acaravci and Ozturk (2010), and Shimalis (2017) are studies in this group.

Taking four Congo basin countries, namely:- Cameron, Congo, Gabon, and the Democratic Republic of Congo Hilaire and Fotio (2015) assessed the nexus by including population density, industrial activity, and trade openness into the nexus during 1978 to 2012. The study found evidence for the existence of a long-run co-integrating equilibrium relationship between the variables. The study further found energy consumption, economic growth, population density, and industrial activities significantly accelerate carbon emissions, while trade openness does not significantly affect carbon emissions in the analyzed countries.

Taking evidence from Bangladesh, Oh and Bhuyan (2018) examined the relationship between energy consumption, economic growth, population density, trade openness, and carbon dioxide (CO_2) emission during the period from 1975 to 2013. The examination found a statistically significant positive impact of energy consumption on CO_2 emission in both the short and long-run. Further, the result found a statistically significant positive impact of population density in the long-run, but its impact is statistically insignificant in the short-run. Also, the result reveals the impact of economic growth and trade openness is negative but statistically insignificant in both the short and long-run. Oh and Bhuyan concludes that the concerning body in the country should practice the policy measures in order to generate the environmentally clean energy alternative which not pollute much the environment.

Furthermore, Hassan and Nosheen (2018) investigated the impact of air transportation, economic growth, energy demand, population density foreign direct investment and trade in Pakistan between 1990 and 2017. The investigation found a statistically significant and positive impact of air transportation, energy consumption, economic growth and population density on the three emission indicators (CO_2, NO_2, and methane). However, the study further suggests an insignificant impact of foreign direct investment and trade in CO_2, NO_2, and methane emissions.

For the same country (Pakistan), Mahmood and Chaudhary (2012) analyzed the impact of foreign direct investment, population density, and share of manufacturing value added on carbon emissions covering the period from 1972 to 2005. The study found a long-run co-integrating relationship between the variables and all of the variables under study positively impact carbon emission and contribute to the pollution in Pakistan.

Taking multiple country case, Saboori and Sulaiman (2013) tested the co-integration and causal relationship between economic growth, energy consumption, and carbon emission on a sample of selected Association of Southeast Asian Nations (ASEAN) countries covering the period 1971-2009. The results found a long-run co-integrating relationship between the variables and statistically significant positive impact of energy consumption on carbon emissions of the countries in both the short and long-run, indicating that energy consumption facilitates the countries carbon emission over time. The Granger test found bidirectional causality between energy consumption and carbon emission in the countries under study, indicating energy consumption and carbon emissions are highly correlated to each other.

In other multiple country study, Acaravci and Ozturk (2010) for 19 European countries analyzed the causal relationship between per capita energy consumption, per capita real income and per capita CO_2 emission. The analysis found evidence for the existence of the Inverted-U shaped curve (EKC) hypothesis in Denmark and Italy. The result also suggests a long-run relationship between per capita CO_2 emission, per capita energy consumption, per capita real income and the square of per capita real income only for Denmark, Germany, Greece, Iceland, Italy, Portugal, and Switzerland. The cumulative sum and cumulative sum of squares tests found that the estimated parameters are stable for the sample period.

Halicioglu (2009) and Ozturk and Acaravci (2010) analyzed the short- and long-run dynamic causal relationship between energy consumption, economic growth, carbon emissions in Turkey between 1960 and 2005 and 1968 and 2005, respectively by adding foreign trade and employment, respectively into the nexus. The results indicated that there is a significant long-run equilibrium relationship between the variables. Halicioglu (2009) found economic growth in Turkey is the most significant variable in determining the carbon emissions followed by energy consumption and foreign trade. However, Ozturk and Acaravci (2010) confirmed the EKC hypothesis is invalid for Turkey. Further, the Granger test in this study found neither CO_2 emissions nor energy use exerts a significant impact on economic growth (income), but employment causes income in the short-run.

Recently, Shimalis (2017) investigate the environment- energy–growth nexus by including urbanization, population, financial development, and trade openness using evidence from Ethiopia during the period 1970-2014. The investigation used Autoregressive distributed lag (ARDL) and multivariate framework of Toda-Yamamoto procedure and found evidence of a long-run co-integrating relationship between the variables of interest. The result further found energy consumption, population, trade openness and economic growth statistically significantly and positively affect CO_2 emission, but economic growth squared significantly and negatively influences CO_2 emission, confirming the validity of EKC hypothesis in the short-run. The Granger test found bidirectional (feedback) relationship between energy consumption, CO_2 emission, and urbanization. Furthermore, the Granger test results reveal financial development, population, and urbanization causes economic growth and also economic growth causes CO_2 emission.

Using Panel-Autoregressive Distributed Lags (Panel-ARDL), Asongu et al (2015) and Poku (2016) assessed the long and short-run relationship between energy consumption, CO_2 emission and economic growth using evidence from 24 African countries covering the period from 1982 to 2011 and Sub-Saharan African countries during the period 1990-2010, respectively. The assessment found evidence for a long-run relationship among the variables of interest. The study by Asongu et al (2015) found stable error correction mechanism and at the time of disequilibrium, only energy consumption adjusts towards its long-run equilibrium. The Granger test found long-run causality runs from economic growth and CO_2 emissions to energy consumption and from both CO_2 emissions and energy consumption to economic growth. Furthermore, the Granger test further found no causality runs from energy consumption to economic growth in the short run, but the reverse causality is observable. Poku (2016) found a highly statistically significant positive impact of population and urbanization on carbon emission in both the short and long-run. Poku concludes carbon emissions in highly populated counties grow faster in comparison to the countries with a small population.

Using Vector Autoregressive (VAR) technique, Endeg et al (2016) examined the three-way linkage between energy consumption, income, and CO_2 emission by including urbanization in Ethiopia over the period 1970/71 to 2010/11. The study found an insignificant long-run relationship between energy use and CO_2 emission, indicating the country's contribution to CO_2

emission from coal consumption in the different sector is very low. Also, the result confirmed the existence of the EKC. The Granger test found causality running from energy consumption to economic growth and urbanization and also from economic growth and urbanization to CO_2 emission.

Utilizing the same econometric approach (VAR), Esso and Keho (2016) examined the long term Granger causal relationship between economic growth, energy consumption and CO_2 emission using evidence from a sample of 12 selected Sub- Sahara African countries over the period 1971-2010. The study found a mixed result in terms of causality direction across countries. The study result further found energy consumption and economic growth results in an increase in CO_2 emissions in most countries in the long-run.

To conclude, in the review of the empirical literature section, several related studies covering developed as well as developing countries concerning the effect of energy consumption, economic growth and other important deriving factors on carbon dioxide emission. From the above empirical studies one can understand that their finding on the relationship and causation between energy consumption, economic growth, carbon dioxide emission, and other important control variables is inconclusive and basically depend on the methodology and types of data adopted, countries and types of variables addressed, and time period covered. The above literature survey also suggests that none of the studies on the nexus between energy consumption, economic growth, population density, urbanization, and carbon dioxide emissions has been done in East Africa in the panel context. Therefore, the present study contributes to the existing literature and ongoing debate on climate change issues by examining the effect of energy consumption and economic growth on carbon dioxide emission in East Africa region by incorporating important demographic variables such as population density and urbanization into the modeling framework. The investigation in this study used the newly developed heterogeneous panel co-integration technique which is Panel-Autoregressive Distributed Lags (Panel-ARDL) and which has rarely been used to investigate the climate change related issue. The above literature survey suggests that most panel studies have employed the homogenous frameworks where the co-integrating vectors are assumed to be identical for all panel units, except Asongu et al (2015) and Poku (2016). However, this study differs from their work. Unlike Asongu et al (2015) and Poku (2016), this study used unbalanced data, demeaned data to eliminate the spatial correlation between the error terms of the cross-section as suggested by Pesaran et al (1997; 1999), and a number co-integration tests in order to check consistency or robustness of the result. Therefore, this study contributes to the existing literature by filling the above-mentioned gaps observed in previous studies.

CHAPTER THREE
DESCRIPTIVE STUDY

3.1 Introduction

This chapter introduces the types, sources, historical trends and descriptive statistics of the data on carbon dioxide emission, total primary energy consumption, economic growth, population density and urbanization over the analyzed period for the sample study of 14 East African countries. Section 3.2 presents the data types and sources for the data on candidate variables such as carbon dioxide emission, economic growth, energy consumption, population density, and urbanization. Section 3.3 presents the historical carbon dioxide emissions, economic growth, energy consumption, and population density and urbanization paths or trends for the countries covered in the study over the analyzed years. Section 3.4 describes the descriptive statistics of the candidate variables.

3.2 Types, sources and measurement units of the data

Annual time series data spanning over 37 years, from 1980 to 2016, on carbon dioxide emission (measured in million tonnes of carbon dioxide), real per capita GDP (measured in US $), total primary energy consumption (measured in Quadrillion British thermal unit), population density (measured in people per square kilometer of total land area) and urbanization (measured in total urban population) were collected from different sources for 14 East African countries:- namely, Ethiopia, Burundi, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Rwanda, Uganda, Zambia, Comoro, Zimbabwe, Tanzania and Malawi.

All the variables except total primary energy and carbon dioxide emission were obtained from the World Bank World Development Indicators database (WB, 2018). The total primary energy consumption and carbon dioxide emissions data were obtained from the U.S Energy Information Administration (EIA, 2018) and Global Carbon Atlas (GCA, 2018) databases, respectively.

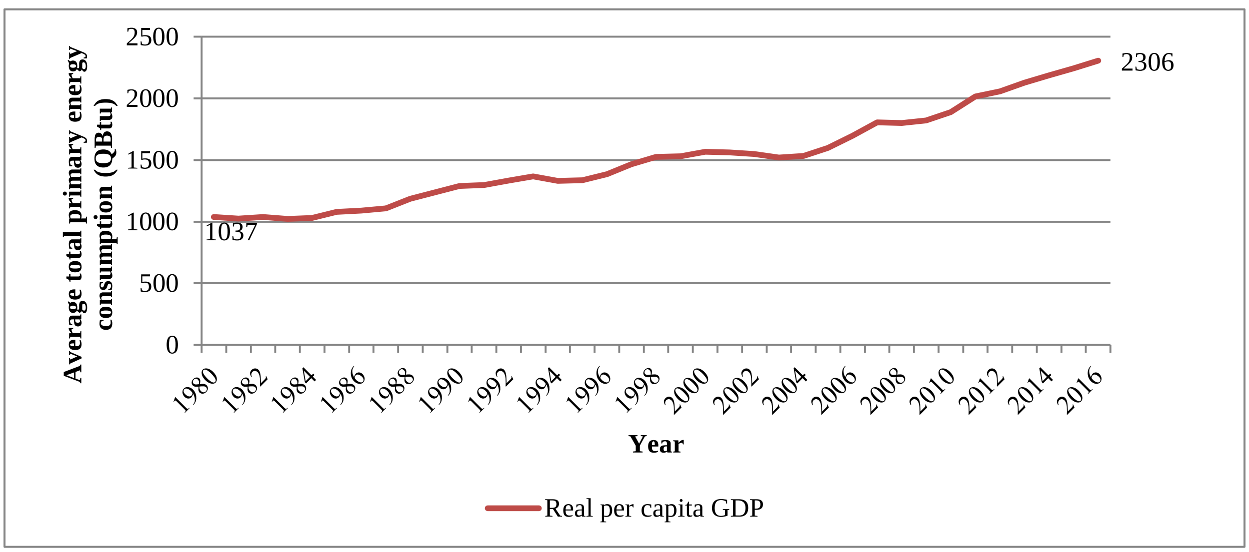
In this study, only 14 countries were used in the analysis due to a lack of recent and complete data for the rest of East African countries. The period of the study goes only up to 2016, due to a lack of more recent data for the countries under analysis. Furthermore, the period covered by the data varies across countries: 1980-2016 for Burundi, Comoros, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Seychelles, Zambia, and Zimbabwe; 1981-2016 for Ethiopia; 1982-2016 for Uganda and 1988-2016 for Tanzania. Therefore, the sample incorporates a time series of a cross-section, the data sample was used as a panel data.

3.3 Trend analysis

3.3.1 Trend of Economic growth in the countries under study

East Africa is currently one of least developed, but rapidly developing region in the world. Available data shows that, on average, real per capita GDP in the 14 countries of the region grew from almost $1037 in 1980 to $2306, representing $1269 more real per capita GDP than the year 1980, which is more than double. The countries have experienced strong economic growth in years under investigation (1980-2016), and real per capita GDP grew from almost $1037 in the year 1980 to $2306 in the year 2016 recording a remarkable average annual growth rate of 2.21% (see figure 3.1).

Figure 3.1: Historical trend of average real per capita GDP of the countries under study



Source: Own calculation depending on World Bank data

However, this positive growth has not been gradual. From the figure, the countries' average real per capita GDP is slightly decreasing from the year 1980 to the year 1981 by a yearly rate of change of -1.21 % and then it slightly increases in the immediate year till 1982 with a yearly rate of change of 1.1 %.

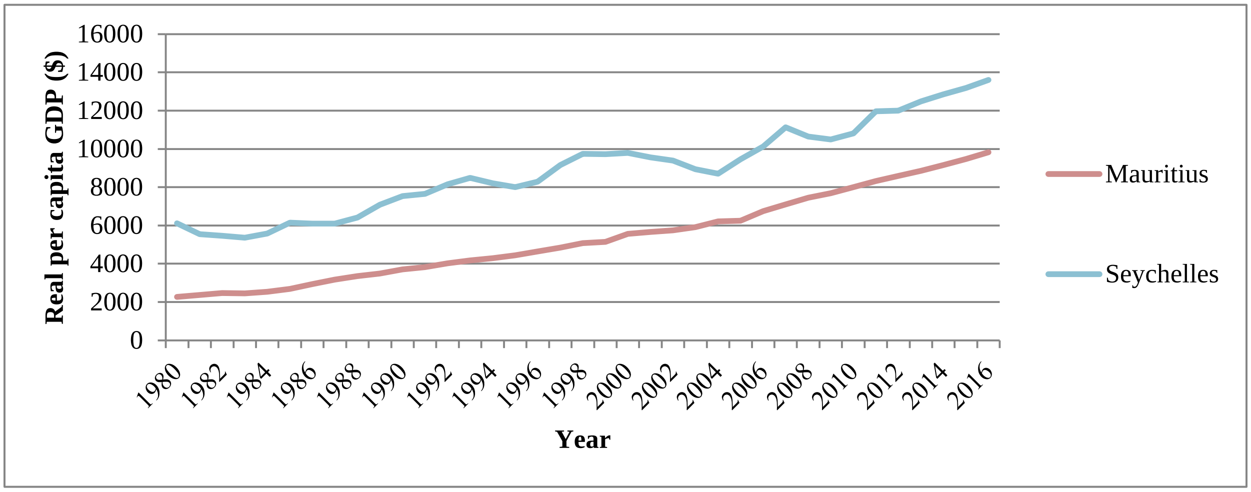
The lowest value of average real per capita GDP ($1022) was reached in the year 1983. It can be observed, over the period 1984 to 1993, average real per capita GDP has been increased with the period's average rate of change of 2.98 % and experienced a slight decrease in the year 1994 by recording the yearly rates of change of -2.74 %. However, it has started to modestly increase from the year 1995 to the year 2007, despite some fluctuation over the period. But in the year 2008, it has experienced a slight decrease compared to the year 2007. In this year, the average real per capita GDP fall by a yearly rate of change of -0.344 %, mainly related to the effect of the economic crisis in the world at that period.

From the year 2009 onwards the average real per capita GDP has been increased remarkably. To be noted, the average real per capita GDP of the countries has experienced remarkable positive growth performance year by year starting from the year 2009 and till the year 2016. Over this period, it grows by the period's average yearly rate of change of 3.15 %. From this, one can understand that dynamic changes of real per capita GDP in the region is quite impressive over the analyzed years (1980-2016).

Even though the average real per capita GDP of the countries under study has experienced almost steady increasing trend over the analyzed years, its historical trends vary considerably in each country under study. Therefore, in order to capture potential differences in the historical trends of the variables (real per capita GDP) between the countries under investigation, it is interesting to consider their trends in each country separately. The following section highlights the historical trends of real per capita GDP by country covered in the present study.

Figure 3.2 and 3.3 shows the changes in the real per capita GDP starting from the year 1980 to the year 2016 for the candidate countries of the study. Real per capita GDP follows a relatively steady upward trend in Mauritius and also in Seychelles with some fluctuations over the analyzed period (see figure 3.2). It can be observed the Seychelles real per capita GDP curve stay above Mauritius's curve throughout the analyzed period, meaning the level of real per capita GDP is the highest for Seychelles in reference to Mauritius. The reason why these two countries treated separately is to view the trend of the variable clearly. According to the World Bank (2018) country grouping, these two countries are grouped high and upper middle-income country, respectively.

Figure 3.2: Historical trend of real per capita GDP in Mauritius and Seychelles

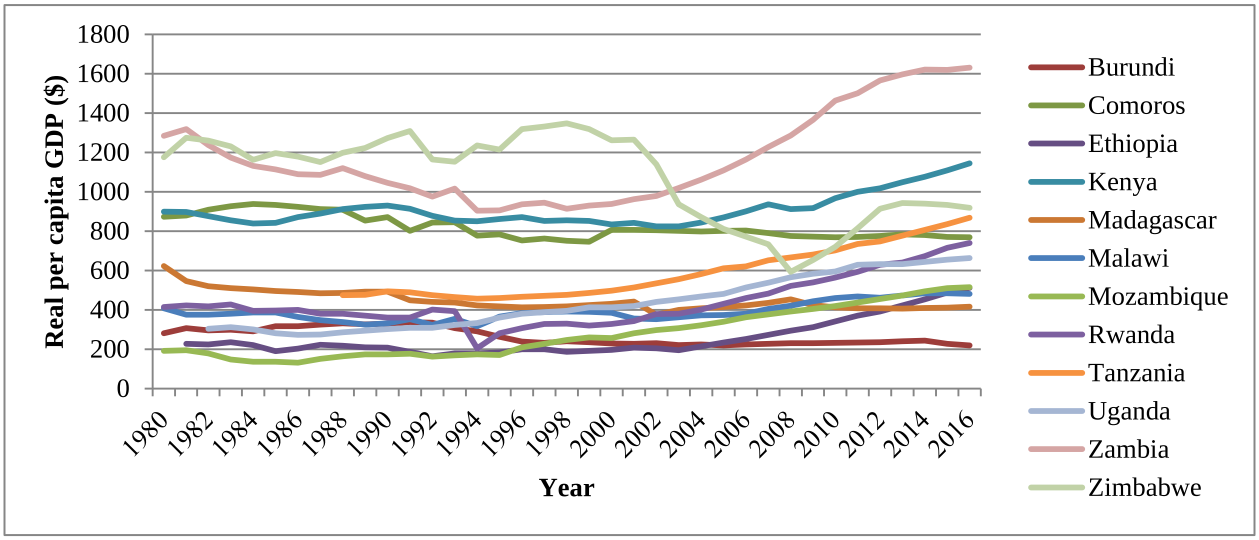


Source: World Bank

During the period under investigation (1980-2016), real per capita GDP increased by the average annual growth rate of 4 % and 2.3%, respectively in Mauritius and Seychelles and reaching $9822 and $13598, respectively in 2016. From this, Mauritius has registered higher and consistent remarkable growth in real per capita GDP in reference to Seychelles over the analyzed period. Such growth is mainly correlated with the country's performance in terms of political stability, strong macroeconomic management, increased foreign direct investment, good institutions; an outward market-driven strategy; careful fiscal, exchange rate, trade, investment and monetary policies and the careful overall planning and policy choices (ADB, 2017; Republic of Mauritius, 2016). Further, "the deriving sectors of Mauritius's real per capita GDP were tourism, financial services, retail trade, and the Information and Communication Technology (ICT) sector" (the Republic of Mauritius, 2016).

Figure 3.3 illustrates the real per capita GDP trends for the remaining candidate countries of the study. As illustrated in the figure, the real per capita GDP has increased in almost all countries in the study, except Burundi, Comoros, Madagascar, and Zimbabwe. In other words, real per capita GDP relatively deteriorated in Burundi, Comoros, Madagascar, and Zimbabwe over the time period under investigation in reference to other countries. During the time period under investigation, the average annual rate of change of real per capita GDP in Burundi, Comoros, Madagascar, and Zimbabwe is -0.58 %, -0.3 %, -0.98 %, and -0.4%, respectively. Over the study period, Madagascar recorded the highest negative change in real per capita GDP followed by Burundi, Zimbabwe, and Comoros.

Figure 3.3: Historical trend of real per capita GDP by country



Source: World Bank

The deterioration of real per capita GDP in these economies is basically related with some country-specific problems. The downward spirals or negative change of Burundi's economy can be largely blamed to the acute socio-political crisis that severely affected the country. The structural and economic difficulties including high population pressures, lack of land, rapid loss of natural resources, lack of a viable secondary sector able to relieve pressures of the primary sectors and political uncertainty stemming from a series of elections in a politically fractionalized environment seriously weakened the country's economy (ADB, 2011; 2015; 2017). In Comoros, negative change in real per capita GDP was largely associated with the ongoing electricity crisis (WB, 2017). Madagascar's negative average growth in real per capita GDP was associated with persistent bad government policies that have had held back economic activities (ADB, 2006).

In Zimbabwe, the coexistence of an increasingly severe economic and political crisis strongly affects the country's economic performance and real per capita GDP between 1999 and 2008. The ongoing crisis in Zimbabwe has largely been related to unfavorable macroeconomic management stemming from lack of government flexibility in undertaking macroeconomic adjustment and unsustainable fiscal as well as monetary policy. Due to this crisis, the engines of

Zimbabwe's economic growth such as agriculture, manufacturing, mining, and tourism have been significantly affected and real per capita GDP has highly deteriorated (ADB, 2002; 2004). In addition, the country's entry to the Democratic Republic of the Congo (DRC) war in August 1998 was also a contributory factor to the country's economic downward spiral (Kanyenze et al, 2017). Since 2009 the country's real per capita GDP has increased gradually. This was largely driven by the remarkable performance in the agriculture, hunting, and fishing; real estate and health sectors (the Republic of Zimbabwe, 2016).

Further, real per capita GDP has tremendously increased since the starting time of the study in other countries. It is notable that the real per capita GDP has been increased in Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda and Zambia and reaching $511, $1143, $481, $514, $738, $867, $662, and $1629, respectively in 2016 (WB, 2018). Over the analyzed years, the average annual growth rate of real per capita GDP in these countries is 2.48 %, 0.68 %, 0.57 %, 2.94 %, 2.29 %, 2.13 %, 2.29 %, and 0.72 %, respectively.

In comparison, the two countries that represent the highest real per capita GDP are Seychelles and Mauritius at $13598 and $9822 in 2016, respectively (see figure 3.2). However, the average annual growth rate of real per capita GDP rank place of Seychelles is the third one accounted from the year 1980 to 2016, with a rate of almost 2.3 %. Mauritius has the first highest real per capita GDP average annual growth rate with 4 % followed by Mozambique (2.94 %) and Ethiopia (2.48 %).

Following the two high and upper middle-income countries (Seychelles and Mauritius respectively) the two countries that represent the highest real per capita GDP are Zambia and Kenya with almost $1629 and $1143 in 2016, respectively (see figure 3.3). The average annual growth rate of real per capita GDP rank place of Zambia and Kenya is seventh and eighth with a rate of 0.72 % and 0.68 %, respectively. According to the World Bank (2018) country grouping, these two countries are also grouped as lower middle-income countries.

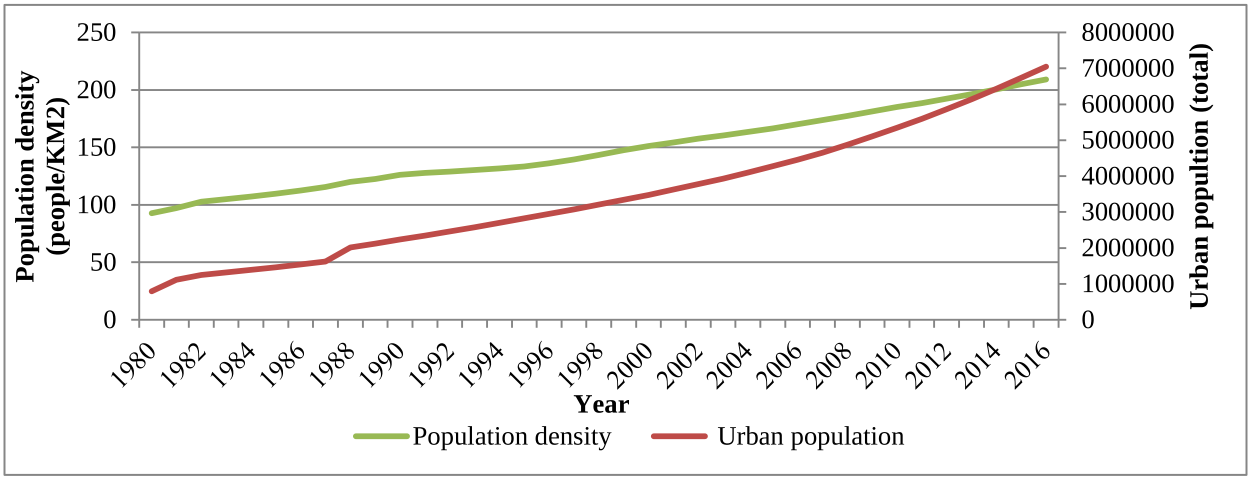
Even though the growth rate of real per capita GDP is deteriorated over the years, Zimbabwe is the fifth country with real per capita income in 2016. In the same year, Burundi recorded the lowest real per capita GDP ($218) followed by Madagascar ($416). This ranks Madagascar and Burundi the thirteenth and fourteenth place in comparison to other countries. However, the average annual growth rate of real per capita GDP rank place of the two countries (Burundi and Madagascar) is fourteenth and thirteenth one with an average annual growth rate of -0.59 % and -098 %, respectively.

However, the recent 17 years data (2000 to 2016) shows that Ethiopia, Rwanda, Mozambique, Mauritius, Tanzania, and Zambia in that order experienced quite impressive growth in real per capita GDP with an average annual growth rate of 6 %, 5 %, 4.14 %, 3.8 %, 3.46 %, and 3.38 %, respectively. In this period, all candidate countries of the present study have recorded remarkable performance in terms of real per capita GDP growth, except for Zimbabwe. From this one can understand that Ethiopia is the country with the fastest growth rate compared to other candidate countries of the present study over the last 17 years.

3.3.2 Trend of demographic growth in the countries under study

Recently, East Africa has experienced quite impressive growth in both urbanization and population (UNPD, 2018). Available data show that the region’s population and urbanization have been increasing remarkably over the analyzed years. Figure 3.4 illustrates the average population density trend compared to urban population evolution since 1980 for the candidate countries of the study. From the figure, one can see that both population density and urban population have been increased throughout the analyzed period. Specifically, the average annual rate of change of population density and urbanization is 2.22 % and 6.24 %, respectively. From this, one can understand that the growth of population in the countries under study is quite impressive. This is because the total area of land is more or less fixed over the years; the growth of population density implicitly indicates the rate of growth of population. Further, urbanization also captured by the urban population growth and over the years under consideration the growth of urban population via the rural-urban migration and natural rate of growth within the urban population also quite high.

Figure 3.4: Historical trend of average population density and urbanization of the countries under study



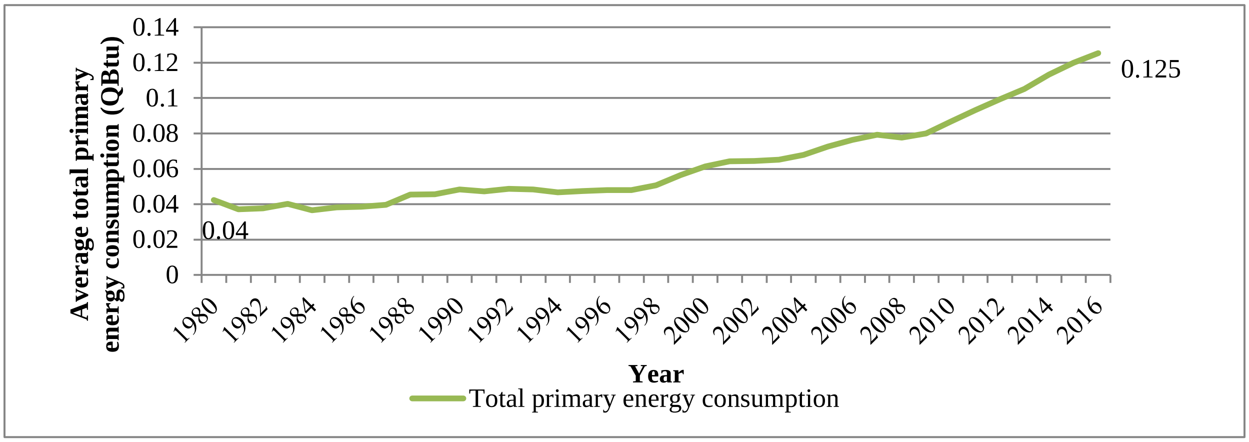
Source: Own calculation depending on World Bank data

Figures in APPENDIX A in the appendices part of the paper depicts the time series plot or historical trends of population density (people per square kilometers of total land area) and urban population (total), which marks the level of population dynamics of the respective country. From the figures, one can observe a very similar upward trending population density and urban population in almost all countries in the sample over the analyzed years. However, in Rwanda, the population density series experienced a significant drop in the year 1994 due to the genocide of the period. Specifically, the average annual rate of change of urban population in Rwanda and Uganda in that order has the highest amounted 3.66 % and 2.96 %, respectively, while Mauritius has the lowest accounting -0.093 %. Regarding population density, Uganda, Ethiopia, Malawi, and Tanzania in that order have the highest annual average rate of growth amounted 4.26 %, 3.23 %, 2.96 %, and 2.94 %, respectively. Mauritius and Seychelles have the lowest annual average rate of growth in terms of population density over the time period under investigation. From this, one can understand that on average population grow fast in Uganda and Ethiopia which is observed from the high average annual growth rate of population density. Further, rapid urbanization is also displayed in Rwanda followed by Uganda which is noticed from a fast average annual rate of growth of the urban population over the time period under analysis.

3.3.3 Trend of energy consumption in the countries under study

Related with the region's growth performance in economics and demographics energy demand significantly increasing. Available data show that the total primary energy consumption in the region has experienced quite impressive growth even though its consumption structure is inefficient and pollution dependent (see figure 3.5).

Figure 3.5: Historical trend of average total primary energy consumption in the countries under study



Source: Own calculation depending on Energy Information Administration data

From the figure, the level of average total primary energy consumption of the candidate countries of the study follows an upward trend, despite some setbacks. Overall, the average total primary energy consumption for the candidate countries increased from almost 0.042QBtu in the year 1980 to almost 0.125QBtu in the year 2016, representing a rise of 197.62% over the analyzed period. From this, one can understand that a dynamic change of total primary energy consumption is quite impressive over the analyzed years (1980-2016).

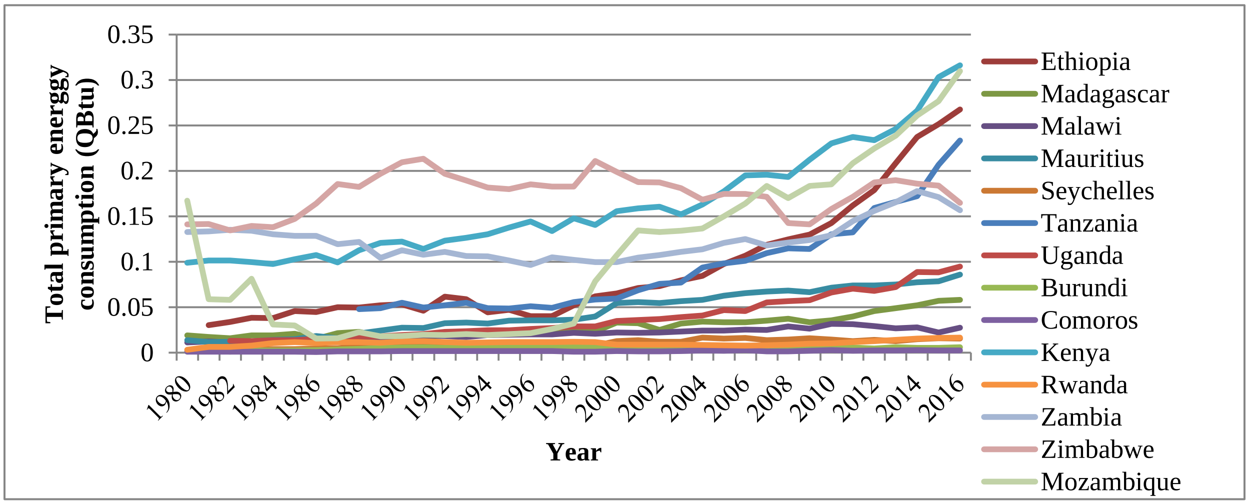
The countries' energy consumption growth has not been gradual. As it can be observed the level of total primary energy consumption is decreasing from the year 1980 to the year 1981 by a yearly rate of change of -12.38 %, and then slightly increases in the immediate year till 1983, with a yearly rate of change of 4.17%. The lowest value of the total primary energy consumption (0.036QBtu) is reached in the year 1984. It can be observed, over the period 1984 to 1993, the total primary energy consumption has been increased with the period's average rate of change of 2.92 % and a slight decrease in the year 1994 by recording the yearly rates of change of -3.22 %.

However, the countries' total primary energy consumption has started to modestly increase from the year 1995 to the year 2007, despite some fluctuation over the period. But in the year 2008, total primary energy consumption has experienced a slight decrease compared to the year 2007. In this year, the total primary energy consumption dropped by a yearly rate of change of -1.99 %. This is mainly related to the effect of the economic crisis in the world at that period. From the year 2009 onwards the total primary energy consumption has been increased remarkably mainly related to the region's economic growth performance of the period.

The same as real per capita GDP trend, the total primary energy consumption of the region experienced remarkable positive growth performance year by year starting from the year 2009 and till the year 2016. Over this period the variable (total primary energy consumption) grew by an average yearly rate of change of 6.18 %, which is quite impressive. From this one can understand that the energy demand in East Africa has been increasing recently.

Looking at the historical trends of each country's total primary energy consumption, it is possible to observe significant variation over the years under investigation. Available country-level data shows that the historical trends of total primary energy consumption in the countries under analysis have shown a significant variation from country to country and from year to year over the period under investigation (see figure 3.6). Figure 3.6 illustrates the historical trends of the total primary energy consumption in the candidate countries of the study.

Figure 3.6: Historical trend of the total primary energy consumption by country



Source: Energy Information Administration

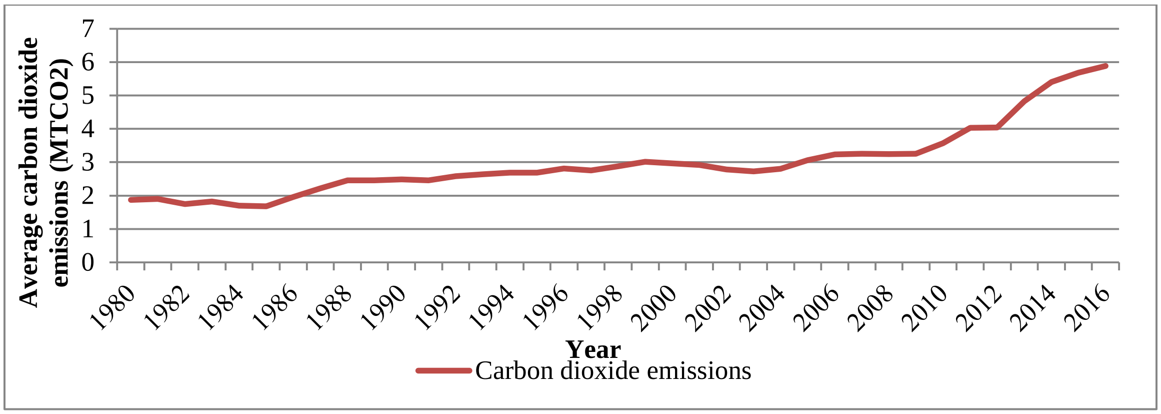
Observing figure 3.6 one can see clearly that the total primary energy consumption has been increasing in all countries, despite some setbacks. The country with the highest total primary energy consumption in the year 2016 is Kenya with 0.316QBtu followed by Mozambique (0.30QBtu), Ethiopia (0.267QBtu), Tanzania (0.233QBtu), Zimbabwe (0.164QBtu), and Zambia (0.156QBtu). In the same year, Comoros recorded the lowest total primary energy consumption with 0.002QBtu followed by Burundi (0.006QBtu). However, in terms of study period average annual growth rate, the highest is for Burundi with 7.8 % per annum, followed by Ethiopia (6.8 %), Mozambique (6.57 %), Seychelles (6.44 %), and Uganda (6.11 %). In contrast, the lowest average annual growth rate is for Zambia with 0.59 %, followed by Zimbabwe (0.64 %).

Within the analyzed period, the candidate countries of the study experienced different performance in terms of the total primary energy consumption growth at different time horizons. Before 2000, the rate of increase in energy consumption is relatively slower than its growth rate after 2000 in eight countries such as Comoros, Ethiopia, Kenya, Madagascar, Mozambique, Tanzania, Uganda, and Zambia. This is observed from the average annual growth rate of total primary energy consumption between the two periods. Over the period 1980 to 2000, the average annual growth rate of total primary energy consumption the above listed countries is 5.8 %, 4.85 %, 2.35 %, 3.9 %, 6.17 %, 1.89 %, 5.59 %, and -1.23 %, respectively, whereas over the period 2000 to 2016, its growth rate is 8.57 %, 9 %, 5 %, 6.4 %, 8.83 %, 8.7 %, 6.11 % and 2.83 %, respectively. From this, one can understand that the demand for energy in these countries more impressive over the period 2000 to 2016, in comparison to the period 1980 to 2000. In contrast, the remaining six countries total primary energy consumption growth is slow during the period 2000 to 2016 in comparison to the period 1980 to 2000. This implies energy consumption demand in almost all countries has been increasing over the period under investigation.

3.3.4 Trend of carbon dioxide emission in the countries under study

According to the Energy Information Administration (EIA, 2016), strong economic growth performance and growing population are considered to be the major deriving factors behind increasing energy demand. And, energy consumption and economic growth, as well as demographic factors such as population and urbanization, are also among the major factors that increase the atmospheric concentration of CO_2 emission. In developing countries, particularly East African countries, growth in energy consumption, output, population, and urbanization are quite impressive in recent decades. As clearly discussed above, the countries in the region have experienced a remarkable performance both in economic growth and energy consumption as well as demographics over the time period under investigation. Such growth has an implication on the anthropogenic emission of carbon dioxide. Accordingly, the following section highlights the historical trends of anthropogenic emissions of carbon dioxide in the region's countries over the time period under investigation.

Figure 3.7: Historical trend of average carbon dioxide emission of the countries under study



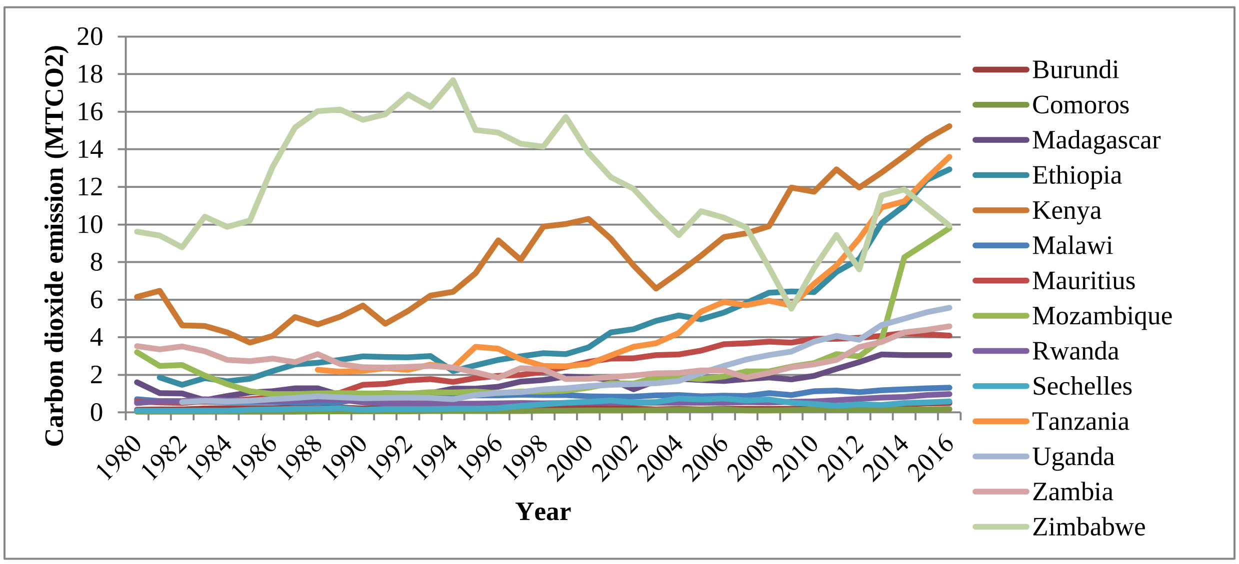
Source: Own calculation depending on Global Carbon Atlas data

Figure 3.7 shows the changes in the average anthropogenic emission of carbon dioxide starting from the year 1980 to the year 2016 for the 14 East African countries covered in the present study. From the Figure, one can see that the level of average anthropogenic emissions of carbon dioxide is increasing impressively over the years under study. In 2016, anthropogenic emissions of carbon dioxide in the region reached almost 5.88$MTCO_2$; representing a rise by 215.4% in comparison 1980, when it was almost 1.87$MTCO_2$ (see Figure 3.7). However, such growth has not been gradual. Carbon dioxide emission is decreasing from the year 1980 to the year 1985 with few ups and downs and reached the study period's lowest value in the year 1985 (1.68$MTCO_2$). Over this period or from 1980 to 1985, its average annual rate of change is amounted -1.64 %. Since the year 1986, the level of carbon dioxide emissions starts to slightly increase with few setbacks till the year 1999, and then it starts to modestly decrease for the year 2000 to 2003.

Over the period 1986 to 1999, the level of anthropogenic emissions of carbon dioxide grew by a yearly average rate of growth of 4.37 %, while over the period 2000 to 2003, it dropped by -2.4 % on average. From the year 2004 onwards, the level of anthropogenic emissions of carbon dioxide has experienced a remarkable increase, even the recent five years data shows that its growth is quite impressive which amounted 8 %, per annum. From this, one can understand that the anthropogenic emission of carbon dioxide has been increasing over the analyzed years (1980 to 2016).

Similar to energy consumption and economic growth trends, carbon dioxide emissions trends also vary by country even though its trend is more or less exhibits steady upward for the candidate countries in general.

Figure 3.8: Historical trend of carbon dioxide emission by country



Source: Global Carbon Atlas

Observing figure 3.8, one can see more or less similar upward trends of carbon dioxide emission, despite some ups and downs, except for Zimbabwe with reference to that of total primary energy consumption discussed earlier. Similar to that of total primary energy consumption trend, Zimbabwe is the country with the highest stock of carbon dioxide emission early three decades of the analyzed period, whereas starting from 2008 Kenya's carbon dioxide emission outpaces Zimbabwe's emission. Even after 2014, the level of carbon dioxide emission in Ethiopia and Tanzania dominates Zimbabwe's emission.

In the year 2016, the country with highest carbon dioxide emission stock is Kenya with 15.32 $MTCO_2$ followed by Tanzania (13.6$MTCO_2$) and Ethiopia (12.94$MTCO_2$). On the other hand, the country with the lowest carbon dioxide emission in the same year is Comoros with 0.18MTCO2 followed by Burundi (0.5$MTCO_2$), Seychelles (0.58$MTCO_2$), and Rwanda (0.98$MTCO_2$).

Specifically, in terms of average annual growth rate, Uganda, Tanzania, Seychelles, Ethiopia, and Mauritius are the country with rapid carbon dioxide emission growth registering 7.22 %, 7 %, 6.64 %, 6.11 %, and 5.74 %, respectively, while slower carbon dioxide emission growth is for Zimbabwe with 1.22 %, per annum, followed by Zambia (1.28 %) and Malawi (2 %).

Similar to total primary energy consumption, the candidate countries of the study experienced different performance in terms of the total primary energy consumption growth at different time horizons within the analyzed period. This is observed from the average annual rate of change of carbon dioxide emission over the two periods (before 2000 and after 2000). Before 2000, the average annual rate of change of carbon dioxide emission is the highest for Seychelles with 10.59 %, followed by Mauritius (8 %) and Uganda (5.48 %), while the lowest is for Mozambique (-3.45 %), Zambia (-2.6 %) and Rwanda (0.6 %). However, after the year 2000, the level of carbon dioxide emission increases almost all countries. This is observed from its average annual growth rate over the period 2000 to 2016. In this period the average annual growth rate of carbon dioxide emission exhibits a significant increase in all countries under study compared to the period 1980 to 2000, except for Kenya, Mauritius, Seychelles, and Zimbabwe. Over this period, the highest average annual growth rate is for Mozambique with 15.45 %, followed by Tanzania (10.9 %), Uganda (9.26 %) and Ethiopia (9 %). In contrast, Zimbabwe with -0.77 %, followed by Seychelles with 2.19 % are the countries under study that recorded the slowest growth in carbon dioxide emission in the same period. From this one can understand that the level of carbon dioxide emission has been increasing over the analyzed period in almost all countries under analysis mainly correlated with the region's performance in terms of energy consumption, economic and demographic growth.

3.4 Descriptive analysis

3.4.1 Descriptive statistics by country

From table 3.1 in APPENDIX B, in comparison to the other twelve countries, Mauritius and Seychelles have shown the highest variation in terms of real per capita GDP, indicating the countries real per capita GDP are highly scattered in comparison to other countries, while the lowest variation in terms of real per capita GDP is observed in Burundi. From the table, the highest real per capita GDP average is for Seychelles with almost $8918 followed by Mauritius ($5362) and Zambia ($1170), while the lowest real per capita GDP average is for Ethiopia with $254 followed by Burundi ($264) and Mozambique ($275).

Regarding energy consumption, compared to the other countries under analysis, Mozambique and Ethiopia show the highest variation in terms of total primary energy consumption whereas the lowest is displayed in Comoros (see table 3.1 in APPENDIX B). The maximum value of total primary energy consumption measured in quadrillion British thermal units (Quad Btu) is registered in Kenya (0. 3159412) and the lowest value is displayed in Comoros and Burundi, with the minimum value of 0.0007091 and 0.0011472, respectively. The highest total primary energy consumption average is for Zimbabwe with 0.175QBtu and the lowest total primary energy consumption average is for Comoros with 0.0018QBtu. This suggests that Zimbabwe consume the largest share of total primary energy in comparison to the other countries covered in the present study.

From table 3.1 in APPENDIX B, the standard deviation of the variable carbon dioxide emission indicates that Tanzania and Kenya have the highest value, respectively indicating carbon dioxide emission in $MTCO_2$ is more scattered in Tanzania and Kenya whereas Comoros has the lowest along with Burundi. In terms of study period average distribution Zimbabwe, Kenya, Tanzania and Ethiopia in that order have the highest carbon dioxide emissions average with 12.06628$MTCO_2$, 8.24627$MTCO_2$, 5.122059$MTCO_2$ and 4.636117$MTCO_2$, respectively, while Comoros, Burundi, and Seychelles in that order have the lowest carbon dioxide emissions average with 0.0963858$MTCO_2$, 0.2385562$MTCO_2$ and 0.3668368$MTCO_2$, respectively. This implies that, on average, Zimbabwe, Kenya, Tanzania, and Ethiopia in that order are the most emitting countries during the analyzed years.

The standard deviation of population density series indicates Rwanda has more scattered population density ranging from its minimum value of 208.38 to its maximum value of 483.07, whereas Zambia has the lowest indicating less scattered population density in the country (see table 3.1 in APPENDIX B). In terms of average distribution of population density, the highest population density average is for Mauritius with 563 people/ KM^2 followed by Rwanda (322), Comoros (282) and Burundi (259), while the lowest population density average is for Zambia with13 people/KM^2 followed by Mozambique (23), Madagascar (26) and Zimbabwe (30).

Highest standard deviation in terms of urban population is for Ethiopia with 4809385, while the lowest is for Seychelles with 6466.529. This suggests that the urban population is more scattered in Ethiopia and less scattered in Seychelles. The highest urban population average is for Ethiopia with 10076005 followed by Tanzania (9436387) and Kenya (6358557) and the lowest urban population average is for Seychelles followed by Comoros.

3.4.2 Descriptive statistics in the panel

Since the sample incorporates a time series of cross-section, it is used to form a panel data set. The model variables used in this study are measured in a different unit and to operationalize the study, it is important to convert them into a natural logarithm. All the model variables are converted into natural logarithm, except urban population. Urban population annual growth rate is used instead of using natural logarithm for estimation purpose. The panel descriptive statistics result also includes the statistics in natural logarithm and also an annual growth rate of the urban population.

Table 3.2 in APPENDIX B, shows the results of the descriptive statistics of all the variables consisting of 507 observation of each. The standard deviation of the variables shows that the urban population has the highest value (3777127) and total primary energy consumption has the lowest (0.0690706) indicating that urban population is more scattered in the panel ranging from its minimum value of 31229 to its maximum value of 2.03e+07 than other variables and total primary energy consumption is less scattered ranging from its minimum value of 0.0007091 to its maximum value of 0.3159412 and its value is highly concentrated around its mean(0.06647032) than other variables. In terms of growth, the highest variation is also displayed in urban population (2.256448) while the lowest is for real per capita GDP (1.070744).

To conclude, available data suggest that carbon dioxide emission in almost all countries in the sample has been increasing and follows a similar tendency with the countries energy consumption and economic growth as well as demographic indicators such as population density and urbanization over the analyzed period. Moreover, along with carbon dioxide emission, most countries in the region have experienced an upward trend in economic growth, energy consumption, and demographics such as population density and urbanization over the study period. This implies that a sample of economies has to experience a developing phase with respect to the introduction of new industries, manufacturing plants and processing factories into the economy as well as urbanization.

As can be observed from the trend analysis, a sample of countries have shown remarkable performance in terms of output and population growth which causes aggregate demand in the economy to increase and resulted in growth in the energy demand and consumption too. This is observed from the trend of total primary energy consumption in the region showing an almost upward trend over the analyzed period. Much of its increase might be driven by the region's economic growth performance and ever-increasing population which results in high population density and urbanization. In fact, such an increase in energy consumption has an impact on environmental quality and resulted in an increase in the atmospheric concentration of carbon dioxide emission. This is also observed from the positive correlation of total primary energy consumption and carbon dioxide emission in the trend analysis. From this one can understand that the path of carbon dioxide emissions in the region is influenced by the path of economic growth, energy consumption, population density, and urbanization.

This conclusion basically stands for trend analysis, which suggested the growth in output, population density, and urbanization seems to be the deriving factors behind increasing energy demand in the region. An increase in energy consumption, in turn, seems to be the principal deriving factors behind the increase in the atmospheric concentration of carbon dioxide emission since the two series follow the same tendencies over time in almost all countries in the region.

However, the trend and descriptive analysis are insufficient in establishing the nature of the relationship between the model variables (carbon dioxide emissions, economic growth, energy consumption, population density, and urbanization). Therefore, there is a need to conduct an econometric analysis since only empirical estimation confirms the direction and magnitude of the relationship. Accordingly, the conclusions formulated above leads to study a chain of the relationship between carbon dioxide emissions, energy consumption, economic growth, population density and urbanization in an integrated empirical framework for a sample of 14 East African countries.

CHAPTER FOUR
METHODOLOGY

4.1 Introduction

This chapter introduces the methodology used in this study. It highlights the description of the variables, model and equations that capture the relationship between the dependent and independent variables.

4.2 Description of the model variables and expected sign

The description of the model variables under investigation; that is, the dependent and independent variables are explained as follows:

Carbon dioxide (CO_2) emission: Carbon dioxide emission is represented by emissions from fossil fuel consumption. This variable is taken due to the non-existence of recent aggregate data on carbon dioxide emission that includes CO_2 emissions from land use and others for each country, which is only available for the period up to 2014. Due to this reason carbon dioxide emission from fossil fuel consumption, which is available until 2016 is taken to represent the carbon dioxide emission variable. According to global carbon atlas, carbon dioxide emission from fossil fuel includes emissions from the use of coal, oil, and gas (combustion and industrial processes), the process of gas flaring and the manufacturing of cement.

Energy consumption: Energy consumption is also represented by total primary energy consumption. The total primary energy consumption is used to represent total energy use due to the reason stated for carbon dioxide emission. According to U.S energy information administration agency, total primary energy consumption includes the consumption of petroleum, dry natural gas, coal, and net nuclear, hydroelectric, and non-hydroelectric renewable electricity. The consumption of this energy for each country also includes net electricity imports (electricity imports minus electricity exports). And, the consumption of biomass, geothermal, and solar energy not used for electricity generation are also included in total primary energy consumption. Further, non-combustion uses of fossil fuels are also included in the total primary energy consumption. From the discussion in chapter 3, a similar path has been observed between carbon dioxide emissions and total primary energy consumption in almost all of the countries under investigation. Therefore, the present study expects a positive sign for the coefficient of total primary energy consumption.

Economic growth: Economic growth is represented by real gross domestic product per capita since in economic sense real gross domestic product and economic growth is identical. Real gross domestic product per capita, in the World Bank data set, is obtained as gross domestic product divided by midyear population. Therefore, the present study used real gross domestic product per capita as a proxy for economic growth and is used as the best indicator of economic growth, which could proxy the levels of standard of living of the society. The same to that of total primary energy consumption, the path of real gross product per capita and carbon dioxide emissions are too similar in almost all countries, except Burundi, Comoros, and Madagascar. In general, a positive coefficient is expected from real gross domestic product per capita in this study.

Population density: Population density is midyear population divided by land area in square kilometers (WB, 2018). In this study, population density is taken to represent relative growth of population to a fixed resource (land area) available. As clearly observed from the trend analysis of the variables last chapter, the path of population density is steadily increasing relative to land over time because an area of land is constant over the years, the relative growth of population is the major factor responsible for the increase in density. If this is the case, the increase in population in a fixed resource (land area) may be the important factor responsible for the environmental degradation in the form of increased demand for arable, residential and grazing land. In other words, as population increase relative to total land area, population density increase and result in higher pressure on the usage of resources both economic and environmental and leads to higher emissions of pollutants, the most prominent one is carbon dioxide. Further, each additional person in the country creates a certain demand for energy for basic needs such as food, clothing, shelter, and others.

Therefore, the higher is the number of peoples or density, the higher is the demand for energy and fuel to sustain their life. An increase in population density means an increase in population relative to the total fixed land area available, the effect of which is a higher rate of deforestation in the form of demand for cultivable, grazing and residential land as well as for biomass consumption. Given this, such usage of resources indirectly and directly causes environmental degradation. Therefore, the present study expects a positive sign for the coefficient of population density.

Urbanization: Urbanization is proxied by the annual urban population growth. Urban population refers to people living in urban areas as defined by national statistical office whereas the total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship (WB, 2018). Urbanization is a sign of economic growth and standard of living. But its impact of environment pollution is apparent. Rapid urbanization could result or bring a remarkable increase in energy demand. In the urbanization process and the concomitant larger urban areas, activities like large scale construction of infrastructure and buildings require using large amounts of cement in which its production emits a large amount of carbon and other inputs. Further, in the urban area, each urban resident consumes a higher amount of energy relative to a person residing in rural areas; that results in more carbon emissions. It is also observed that; East African countries are currently urbanizing at a relatively fast rate. Therefore, the current study expects a positive sign for the coefficient of urbanization

4.3 Model specification

This section presents a simple model that captures some of the major model variables that can be deriving the anthropogenic emissions of carbon dioxide in a set of East African countries. The lists of the variables to be included in the modeling framework are introduced largely depending on the basis of other empirical analysis.

To investigate the determinants of anthropogenic emissions of carbon dioxide from economic and demographic perspectives in East African countries, the researcher specifies an empirical model following the papers by Shemelis K (2017), that explains Ethiopia's carbon dioxide emission as depending on energy consumption, economic growth, financial development, population and urbanization, and by Ohlan R (2015), that explains India's carbon dioxide emission as depending on population density, energy consumption, economic growth and trade openness. Asongu et al (2015), use panel data analysis for 24 African countries. They model carbon dioxide emissions as a function of energy consumption and economic growth.

Following the above-mentioned papers, the present study incorporates macroeconomic and demographic variables in the modeling framework to examine the determinants of carbon dioxide emissions in East African countries. Therefore, an empirical model is specified as carbon dioxide emission as a function of energy consumption, economic growth, population density, and urbanization. Unlike Asongu et al (2015) this study includes demographic variables such as population density and urbanization that can be augmenting anthropogenic emissions of carbon dioxide in East African countries. The inclusion of demographic variables into the modeling framework is to overcome the problem of omitted variable bias. Among the demographic variables, population density in a sense represents relative growth of population to total fixed area of land available, the effect of which is in per capita land area cultivated, built, grazed and also per capita energy consumed in the form of wood and wood-based energy. This is an important variable that assumed to be a responsible factor for environmental degradation.

In view of the above statement, to establish the relationship between carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita, population density and urbanization, the following reduced form model is proposed:

$CO_{2i,t}$ = f ($TPEC_{i,t}$, $RGDPPC_{i,t}$, $PD_{i,t}$, $UR_{i,t}$)……………………………………........…Equ (4.1)

Where, $CO_{2i,t}$ is carbon dioxide emission from fossil fuel form country i at time t, $TPEC_{i,t}$ is total primary energy consumption form country i at time t, $RGDPPC_{i,t}$ is real gross domestic product per capita form country i at time t, $PD_{i,t}$ is population density form country i at time t and $UR_{i,t}$ is annual urban population growth form country i at time t.

Equation (4.1) suggests that total primary energy consumption, real gross domestic product per capita, population density and urbanization can be the determinants of carbon dioxide emission in fourteen Eastern African countries. In other words, carbon dioxide emission is a function of total primary energy consumption, real gross domestic product per capita, population density and urbanization. Further, Equation (4.1) expressed in an explicit parametric model as follows:

$CO_{2i,t} = \beta_{0i} + \beta_{1i}TPEC_{i,t} + \beta_{2i}RGDPPC_{i,t} + \beta_{3i}PD_{i,t} + \beta_{4i}UR_{i,t} + e_{i,t}$…………...……Equ(4.2)

The residual $e_{i,t}$ represents the cross-section specific error term overtime t, β_{0i} represents the cross-section specific intercept. The slopes β_{1i}, β_{2i}, β_{3i} and β_{4i} are the coefficients of total primary energy consumption, real gross domestic product per capita, population density and urbanization, respectively.

Finally, all the explanatory variables included in the model except urban population growth will be transformed into their logarithmic form for estimation purpose. Such transformation has some advantage in the estimation process. First, it minimizes the fluctuations in the data series or ensures the elimination of possible outliers as well as large coefficients. Second, it allows the measurement of approximate growth rates or it captures growth impacts. Finally, the interpretation of the coefficients gives elasticities. Elasticities are of significance as it would bring to bear the actual responses of the dependent variable to changes in the independent variables. In this context, the elasticities bring the actual responses of carbon dioxide emissions to changes in the level of total primary energy consumption, real gross domestic product per capita, population density and urbanization in the country i at time t or at any point in time. Since it is represented in annual growth form, urbanization variable will not be transformed in its natural logarithm.

In view of the above statement, Equation (4.2) can be rewritten in a logarithmic form as follows:

$$LCO_{2i,t} = \beta_{0i} + \beta_{1i}LTPEC_{i,t} + \beta_{2i}LRGDPPC_{i,t} + \beta_{3i}LPD_{i,t} + \beta_{4i}LUR_{i,t} + e_{i,t} \ldots\ldots\ldots\ldots \text{Equ (4.3)}$$

The term β_{1i}, β_{2i}, β_{3i} and β_{4i} represent the elasticity. All other things are as they are defined earlier.

4.4 The methodology of the study

This study investigates the effects or impacts of selected indicators of demographics and economics activities on anthropogenic emissions of carbon dioxide for the period of 1980 to 2016 for a panel of East African countries. In panel data analysis so far, various approaches have been used to examine the relationship between the variables of interest under investigation. These include pooled OLS, random Effects, fixed effects, GMM estimation techniques and co-integrating regression models such as Fully-Modified OLS (FMOLS) and Dynamic-OLS (DOLS). However, in this study, the Panel-Autoregressive Distributed Lag (Panel-ARDL) co-integration in the form of Unrestricted Error Correction Model (UECM) is used. Panel-ARDL model is preferred over the other standard panel data model because it has a number of advantages over them. These are:

- First, the Panel-ARDL in error correction form is relatively new co-integration test (Pesaran and Shin, 1999; Pesaran, 1997; Pesaran et al 1999).
- Second, it can be applied even with variables with a different order of integration irrespective of whether the variables under investigation are I(1) or I(0) or mixed(Pesaran and Shin, 1999).
- Third, it involves a single equation set up and this makes implementation and interpretation of ARDL estimators simple (Giles, 2013).
- Fourth, it produces both the short run and long run effects simultaneously from the data with large cross-section and time dimensions (Pesaran and Shin, 1999). In other words, Panel-ARDL decomposes the total effects of a variable into its short and long-run components.
- Fifth, it provides consistent coefficients despite the possible presence of endogeneity because it includes lags of dependent and independent variables (Pesaran et al, 1999).
- Sixth, it is good for both large and small sample size and unlike other methods; it produces a statistically significant result in small samples (Pesaran et al, 1999; Narayan, P, 2005).
- Finally, it allows different variables to be assigned different lags in the model (Giles, 2013).

In addition, the data under analysis also fit only the panel-ARDL model among other panel data models. The data under study exhibits a mixed order of integration from the stationary analysis. This suggests only panel-ARDL model fits the data since it can be applied even with variables with a different order of integration irrespective of whether the variables under investigation are I (1) or I (0) or mixed while other models cannot.

Therefore, in order to achieve the objectives of the study, the model of carbon dioxide emissions equation is estimated using Panel-ARDL econometric technique. In order to estimate the relationship between the variables using Panel-ARDL framework, the following procedure is followed:

- First, perform panel unit root tests to ascertain none of the variables under investigation are integrated of order 2 or I (2).
- Second, perform panel co-integration tests to ascertain the existence of a long-run relationship among the variables of interest under investigation. However, this step is considered as optional in most of Panel-ARDL estimation because co-integration can be ascertained from the statistical significance of the long-run coefficients and error correction mechanism. The standard panel co-integration tests require the variables under investigation should be integrated of order one or I(1), but in the case of Panel-ARDL methodology, the variables under investigation can be I(0), I(1) or mixed. Therefore, the standard panel co-integration tests such as Kao (1999), Pedroni (1999, 2004) and others provide less evidence when the variables under investigation are found to be a mixed order of integration. Though the co-integration or the long-run equilibrium relationship of the variables under investigation can be ascertained from the statistical significance of the error correction mechanism or the speed of adjustment term, the present study also utilized the standard panel co-integration test such as Kao (1999) and Wald-test for the robustness of the result.
- Third, run a Panel-ARDL model specification.
- Fourth, determine the optimal lags structure for the model specified in step 3.
- Fifth, estimate the model using the alternative estimators such as Mean Group (MG), Pooled Mean Group (PMG) and Dynamic Fixed Effect (DFE).
- Sixth, perform Hausman (1978) test
- Seventh, select the best fit or consistent estimator based on the outcome of the Hausman (1978) test
- Finally, perform some diagnostic tests for the selected model to ensure the validity, consistency and efficiency conditions before going to interpretation.

4.5 Estimation procedure

4.5.1 Panel unit root test

It is well known that the regression result is consistent and can also be used for forecasting and policy analysis when the variables incorporated in the model under investigation are stationary. A variable is stationary when it's mean; variance and auto-covariance are time-invariant and follow constant movement over time. However, most of the macroeconomic variables in the practical world are non-stationary. This occurs when a variable has a persistent long-run movement or if it is unstable over time. Thus, proper care should be taken to the issue of stationarity of the variables in order to avoid the problem of spurious regression before going to estimation. Spurious regression is common when least square regression is run on unrelated variables which are non-stationary. In this case, one can obtain a significant relationship while the variables are unrelated. In such a case, the study results can be used to infer the behavior of the variables at a single point in time but no for the different period under investigation.

Recently, more attention is being given to the examination of stationarity of the variables in the panel test, and a number of panel unit root tests have been developed, in order to determine the order of integration of the model variables. This study employed three types of panel data unit root tests that accommodate unbalanced panel data. Such tests the Im-Pesaran-Shin (IPS) test developed by Im et al (2003), the Fisher-type Augmented Dickey-Fuller (ADF) and the Fisher-type Phillips Peron (PP) tests developed by Maddala and Wu (1999). Therefore, this study used the IPS test and the two Fisher type tests namely Fisher-type Augmented Dickey-Fuller (ADF) and the Fisher-type Phillips Peron (PP) tests to test integration order of the model variables.

All panel unit roots start on the following autoregressive process of the panel data. Let's consider the following AR (1) process for panel data.

$$y_{i,t} = \alpha_i y_{i,t-1} + \beta_i x_{i,t} + e_{i,t} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots Equ(4.4)$$

Where i=1, 2,…, N, represents cross- section units or observed time series over time t=1, 2,….., T, $x_{i,t}$ indicates the exogenous variables in the model including any fixed effects and individual trend, α_i are autoregressive coefficients, $e_{i,t}$ are the error terms.

If $|\alpha_i| < 1$, then $y_{i,t}$ is said to stationary, and when $|\alpha_i| = 1$, this implies the series $y_{i,t}$ contains unit root or non-stationary series.

4.5.1.1 Im, Pesaran, and Shin (2003) test

As a starting point Im, Pesaran and Shin (2003) used the autoregressive process for panel data given by equation (4.4) and propose the (IPS) a test that can be considered as a panel extension of the Augmented Dickey-Fuller (ADF) test:

So, Im et al (2003) use the following specification of the test:

$$\Delta y_{i,t} = \rho_i y_{i,t-1} + \sum_{j=1}^{qi} \delta_i \Delta y_{i,t-j} + \beta_i x_{i,t} + v_{i,t} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . Equ(4.5)$$

Where $\rho_i = \alpha_i$ -1, q_i is the order of lags for the difference term

Some panel data unit root tests such as Levin et al and Breitung constrain ρ_i be the same across cross-section (that is assumed $\rho_i = \rho$). Im et al (2003) test, on the other hand, allow heterogeneity on the autoregressive coefficient (ρ_i) across cross-sections. In other words, this test enables individual unit root processes through separate ADF regression for each cross section. Thus, allowing ρ_i could vary across the cross-section. This test combines the individual unit root tests to derive a single panel test statistics. A single panel unit root test statistics are generated by averaging the cross section-specific test statistics. After finding the separate ADF regression for each cross-section, the average of the test statistics for ρ_i from the individual ADF regression can be computed. Therefore, the IPS test simply uses the average of the N ADF individual test statistics (t_{iT}), which can be computed as:

$$t - bar_{NT} = \frac{1}{N} \sum_{i=1}^{N} t_{iT} \dots \dots \dots \dots \dots \dots \dots \dots \dots . \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots . . Equ(4.6)$$

Where, t_{iT} is a standard Dickey-Fuller statistic for the i^{th} individual or country.

This statistics can be used to evaluate whether a variable $Y_{i,t}$ has a unit root or not. The test hypotheses are given below:

The null hypothesis of the test can be given as:

H_o: $\rho_i = 0$ for all i. This indicates a coefficient α_i from equation (4.4) equals one. It is well known from equation (2) $\rho_i = \alpha_i - 1$. The null hypothesis holds true or not rejected when ρ_i =0 and this holds when α_i = 1. Therefore, under the null hypothesis $Y_{i,t}$ is non- stationary across individuals or countries.

The alternative hypothesis can also be given as:

$$H_1: \begin{cases} \rho_i = 0, \text{for i} = 1, \ 2, \dots \dots N1 \\ \rho_i < 0, \text{for i} = \text{N1} + 1, , , , , , \text{N} \end{cases}$$

Under the alternative hypothesis, at least a non-zero fraction of the individual process is stationary. In other words, $Y_{i,t}$ is stationary at least in one i (ρ_i<0 for at least one i).

4.5.1.2 Fisher-ADF and Fisher-PP tests

Another panel unit root test, alternative to IPS test is Fisher-type tests developed by Maddala and Wu (1999). Maddala and Wu (1999) suggest a Fisher- type tests such as ADF and PP, which combines the P-values from unit root tests for each cross-sectional unit. In other words, these tests use combined or aggregated P-values from individual time series unit root tests to test for a unit root in panel data. These tests adopt equation (4.5) above and allow heterogeneity of the coefficient ρ_i across cross-sections or countries. The main feature of these tests is that unlike IPS test that use average test statistics, they combine the probability values of the unit root tests from individual cross-sections. However, all the tests the IPS (2003), the Fisher-type ADF and the Fisher-type PP test combine information based on individual unit root tests and also account unbalanced data. Furthermore, these tests are usually implemented using individual ADF and Phillips and Perron unit root tests. All tests asymptotic distribution follows a chi-square (p-test). Since both IPS and Fisher- type tests use equation (4.5) above and also allow heterogeneity of the coefficient ρ_i across cross-sections or countries, their tests hypothesis also follow the same pattern. Therefore, the null and alternative hypotheses of the test are the same as in the case of the IPS test.

In order to investigate the stationary property of every cross-sectional series under investigation, Fisher-type ADF and PP panel data unit root tests use regression of the following equation just like IPS test.

$$\Delta y_{i,t} = \rho_i y_{i,t-1} + \sum_{j=1}^{qi} \delta_i \Delta y_{i,t-j} + \beta_i x_{i,t} + v_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Equ(4.7)$$

Where Δ is a change parameter, and all other things are as they are defined above

The tests null hypothesis: H_o: $\rho_i = 0$, for all i, indicates existences of unit root for all observed time series i over the period t=1, 2… T.

The tests alternative hypothesis: H_1: $\begin{cases} \rho_i = 0, \text{for i} = 1,\ 2, \ldots \ldots N1 \\ \rho_i < 0, \text{for i} = \text{N1} + 1,,,,,, \text{N} \end{cases}$

Alternative hypothesis indicates nonexistence of unit root at least for one i.

To every cross-section of the analyzed time series regression equation (4.7) is used and P-values for every individual unit root tests estimated and then combined to test panel unit root.

Let λ_i be the P-values from any individual unit root test for cross-section i. From this, under the null of unit root for all cross section the asymptotic result can be obtained by using the following general model:

$$\lambda = -2\sum_{i=1}^{N} ln\lambda_i \sim x_{2N}^2$$

Where, λ represents the joint test statistics or aggregated P-value of Fisher-type of ADF and PP test, λ_i represents the probability values from regular DF panel unit root tests for each individual, *i* denotes the cross-section. The joint test statistic above, under the null and the additional hypothesis of cross-sectional independence of the errors terms $v_{i,t}$ in the ADF equation, has a chi-square distribution with 2*N* degrees of freedom.

4.5.2 Panel co-integration test

Following the assessment of the order of integration of the variables under investigation using panel unit root test, panel co-integration analysis is conducted to examine whether the variables of interest under investigation have long run relationship or not. The concept of co-integration refers to situations when the time series present co-movement over the long run. From the economic point of view, such behavior provides evidence of a stable long-run relationship between the variables.

It is well known that co-integration of the variables is tested based on the examination of the residuals of spurious regression or regression with variables that are differenced once (I(1)) (Engle-Granger, 1987). In this case, co-integration or long-run relationship exists when a linear combination of integrated or I(1) variables have a lower order of integration. In the same token, when the variables are difference stationary or I(1), they might have linear combinations that are level stationary or I(0). Statistically, if each time series is integrated of order one and their linear combination is stationary, we can conclude that the variables are co-integrated.

Consequently, when the variables under investigation are integrated with the integration analysis, then panel co-integration test will follow to determine whether a long-run equilibrium relationship exists among the variables of interest.

According to Pesaran and Shin (1999) and Pesaran et al. (2001), in the ARDL technique of estimation the long- run relationship or co-integration among the variables of interest can be carried out using bound test of co-integration in time series version of the analysis. In order to see the bound test of Pesaran et al. (2001), let's consider the time series version of the ARDL (1, 1) model.

$$y_t = \delta_0 + \delta_1 x_t + \delta_2 x_{t-1} + \lambda y_{t-1} + e_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Equ\ (4.8)$$

The re-parameterized form of equation 4.7, can be rewritten as

$$\Delta y_t = \delta_0 + \delta_1 \Delta x_t - (1-\lambda)(\, y_{t-1} - \Omega x_{t-1}\,) + e_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots Equ\ (4.9)$$

Therefore, $(\, y_{t-1} - \Omega x_{t-1}\,)$ is the error correcting term lagged by one period or ECT_{t-1} and $-(1-\lambda)$ is the error correcting parameter which measures the speed of adjustment of the model. See the full re-parameterization into error-correction from in APPENDIX C in appendices part of the paper.

Assuming the maximum lags for the variable to be one, re-parameterized error correction model in equation (4.9) for more than one explanatory variable can reasonably be generalized of as follows:

$$\Delta y_t = \delta_0 + \delta_1 \Delta x_{1t} + \delta_2 \Delta x_{2t} + \delta_3 \Delta x_{3t} + \cdots .. + \delta_k \Delta x_{kt} - (1-\lambda)(y_{t-1} - \Omega_1 x_{1t-1} - \Omega_2 x_{2t-1} - \Omega_3 x_{3t-1} - \cdots - \Omega_k x_{kt-1}) + e_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots Equ\ (4.10)$$

Where, $\delta_1, \delta_2, \ \delta_3, , , , \delta_k$ are coefficients that measures the short –run relationship

$\Omega_1, \Omega_2, \Omega_3,,, , \ \Omega_k$ are coefficients that measure the long-run relationship

Having this, according to Pesaran and Shin (1999) and Pesaran et al. (2001), the long- run relationship or co-integration among the variables of interest can be carried out via bound test approach for co-integration. Such a co-integration test can be performed by formulating the following null hypothesis of no co-integration.

H_0: $\Omega_1 = \Omega_2 = \Omega_3 =, , , , = \Omega_k = 0$ means there is no long-run relationship among the variables of interest

H_1: $\Omega_1 \neq \Omega_2 \neq \Omega_3 \neq, ,, \neq \Omega_k \neq 0$ means there is a long-run relationship among the variables of interest

According to Pesaran and Shin (1999) and Pesaran et al. (2001), the presence of a long-run co-integrating relationship between the variables can be carried out using F-statistics. In order to test the above hypothesis, the computed F-statistics is compared with the upper and lower bound critical values since the name of the test is a bound test. The guideline of the test is: - if the computed F-statistics is higher than the appropriate upper bound of the critical value, the null hypothesis of no co-integration among the variables can be rejected and the alternative hypothesis is accepted. But if it is below the appropriate lower bound, the null hypothesis cannot be rejected, and if it lies within the lower and upper bounds, the result would be inconclusive.

Following this, one can reasonably generalize Pesaran and Shin (1999) and Pesaran et al. (2001) co-integration test of time series analysis for panel data context. Therefore, let’s consider the panel-data version of equation (4.10) above.

$\Delta y_{i,t} = \delta_{i,0} + \delta_{i,1}\,\Delta x_{i,t} + \delta_{i,2}\,\Delta x_{2i,t} + \delta_{i,3}\,\Delta x_{3i,t} + \cdots .. + \delta_{i,k}\,\Delta x_{ki,t} - (1-\lambda_i)(\, y_{i,t-1} - \Omega_{1i}\, x_{1i,t-1} - \Omega_{2i}\, x_{2i,t-1} - \Omega_{3i}\, x_{3i,t-1} - \cdots - \Omega_{ki}\, x_{ki,t-1}) + e_{i,t}$ ……………………….... Equ (4.11)

Given this, a possible generalization of a co-integration test of Pesaran and Shin (1999) and Pesaran et al. (2001), from time series to panel data can be carried out as follows:

The null hypothesis of no co-integration between the variables under investigation from equation (4.11) can be formulated as

H_0: $\Omega_{1i}=\Omega_{2i}=\Omega_{3i}=,,,=\Omega_{ki}=0$ means there is no long-run relationship among the variables of interest

H_1: $\Omega_{1i}\neq\Omega_{2i}\neq\Omega_{3i}\neq,,,\neq\Omega_{ki}\neq 0$ means there is a long-run relationship among the variables of interest

Even though the generalization of the test is possible in this way, the determination of the critical values in the panel data context is not available in the works of literature. Even if the value of F-statistics can be computed using Wald-test of long-run coefficients restriction, the critical values are not available in the panel data context. This divides panel-ARDL techniques of estimation kinds of literature into three based on their co-integration tests. In other words, since there are no critical values for the bound test in the panel data context, literature that used panel-ARDL estimation technique have been grouped into three depending on the way they were carried out the co-integration tests.

The first group of panel-ARDL studies used standard panel co-integration tests in order to decide on the long-run relationship between the variables of interest in the model analyzed. Study by Fuzli and Abbasi (2018) which used Kao (1999) residual-based co-integration test in the analysis of the validity of Kuznets curve of energy intensity for D-8 countries and Poku, A.F (2016) which utilized Pedroni residual based panel co-integration test in the analysis of carbon dioxide emissions, urbanization and population relationship for Sub-Saharan African countries fall in this group. However, there is some limitation to this method. Basically, the standard panel co-integration tests were designed for the non-stationary (integrated of order one) variables and require the variables in the model has to be integrated of order one or I (1). But once the variables in the model are found to be fractionally integrated their power of test statistics becomes low to infer the long-run relationship between the variables and the result is disturbed due to the inclusion of the stationary or I(0) variables. If this is the case, in the panel-ARDL estimation, relying totally on the result of the standard panel co-integration test might not provide enough evidence for the long-run behavior of the variables under study. This is because panel-ARDL methodology captures the case that the variables are fractionally integrated which is not the case in the standard panel co-integration test. This is one of the limitations of the past studies that depend on the co-integration result of standard panel co-integration test.

The second group used the Wald- test of long-run coefficients restriction in order to infer the long-run behavior of the variables in the model. The panel-ARDL study by Kutu and Ngalawa (2016) which used Wald-test of long-run coefficients restriction in the analysis of the dynamics of industrial production in BRICS countries and Aliha et al (2017) which utilized the same procedure in the analysis of the relationship between payment technologies and money demand on the world scale are part of this group. As can be seen above, this method also has limitation. In this method, the critical values are not available in the panel data context even though F-statistics can be provided by the test. However, logically, when the test provides a statistically significant large value of Fisher-test statistics or F-statistics associated with the Wald-test, then there is a long-run relationship among the variables, meaning that the null hypothesis of no- co-integration has to be rejected and vice versa.

The third group of panel-ARDL studies used the statistical significance of the long-run coefficients and error-correction mechanism in order to provide evidence for long-run relationship/co-integration/ among the variables under study. In the same token, this is the most widely and easily used method of co-integration because the long-run relationship is easily ascertained from the statistical significance of the long-run coefficients and error correction mechanism or speed of adjustment term. The panel-ARDL study by Samargandi, et al (2013), Saiful et al (2014) and Pesaran et al (1997; 1999) fall in this group.

Given this, the present study ascertained the long-run relationship between the variables using the three methods used in the past panel-ARDL studies in the literature. This study utilized all of the methods used for co-integration analysis in the panel-ARDL estimation in the literature in order to minimize the limitation of those studies that used only a single method for co-integration. In addition, using the three types of long-run relationship tests is also to check the robustness or consistency of the result across different tests. Specifically, due to the limitations discussed above, the present study used the standard panel co-integration test (Kao (1999)), Wald- test of long-run coefficients restriction as well as the statistical significance of the error-correction term coefficient in order to ascertain the long-run relationship among the model variables.

4.5.2.1 Kao (1999)-Residual based test

Kao (1999) developed two tests for the null of no co-integration in panel data. He proposes Dickey-Fuller and Augmented Dickey-Fuller type tests by considering the special case of where co-integration vectors are homogeneous between individuals, i.e. these tests do not allow for heterogeneity under the alternative hypothesis. The Kao's panel co-integration test using Dickey-Fuller and Augmented Dickey-Fuller type test follow the model highlighted as follows:

$$y_{i,t} = \alpha_i + \beta_1 x_{1i,t} + \beta_2 x_{2i,t} + \ldots + \beta_k x_{ki,t} + e_{i,t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . Equ(4.12)$$

$$y_{i,t} = y_{i,t-1} + u_{i,t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . \ldots Equ(4.13)$$

$$x_{i,t} = x_{i,t-1} + v_{i,t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . \ldots Equ(4.14)$$

Here Kao considers both $y_{i,t}$ and $x_{i,t}$ as random walk series. Therefore under Kaos no cointegration null hypothesis, the residual $e_{i,t}$ from equation (4.12) should be integrated of order one (I (1) or non-stationary). According to Kao (1999), the model in equation (4.12) has common slope coefficients (β) across panel members, varying intercept (α_i) across panel members and fixed effects specification. Given this, both tests (DF and ADF) proposed by Kao is computed using the estimated residuals from equation (4.12) above.

Therefore, Kao's DF type test is computed using the following AR (1) process of estimated residuals:

$$\hat{e}_{i,t} = \rho \hat{e}_{i,t-1} + \pi_{i,t} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . Equ(4.15)$$

While the Kao's ADF type test can also be computed using the following equation:

$$\hat{e}_{i,t} = \rho\hat{e}_{i,t-1} + \sum_{j=1}^{p} \lambda_i \hat{e}_{i,t-1} + v_{i,tp} \ldots \ldots \ldots \ldots Equ(4.16)$$

Where, $\hat{e}_{i,t}$ is the estimated residual from equation (4.12), p is the number of lags in the ADF specification. These lags should be incorporated to take care of possible autocorrelation among$v_{i,tp}$. Therefore, based on the DF and ADF test statistics computed using equation (4.15) and (4.16), respectively, Kao's (1999) co-integration test evaluates whether $y_{i,t}$ and $x_{i,t}$ are co-integrated or not. Thus, the null and alternative hypotheses of the test are:

The null hypothesis of the test:

H_o: ρ =1, indicating the non-existence of co-integrating relationship among $y_{i,t}$ and$x_{i,t}$. In other words, $e_{i,t}$ is integrated of order one or I (1).

The alternative hypothesis of the test:

H_1: ρ < 1, indicating the existence of co-integrating relationship among $y_{i,t}$ and $x_{i,t}$. In other words, $e_{i,t}$ is integrated of order zero or I (0).

4.5.3 Panel-ARDL model

Once the order of integration and the long run relationship of the variables are proven, then one can estimate the appropriate short run and long run parameters by using panel ARDL in the form of Unrestricted Error Correction model (UECM).

Following Pesaran et al (1999), the present study adopts the following general unrestricted panel ARDL (p, q) model specification:

$$y_{i,t} = \sum_{j=1}^{p} \gamma_{i,j}\, y_{i,t-j} + \sum_{j=0}^{q} \lambda_{i,j}\, x_{i,t-j} + \mu_i + e_{i,t} \ldots \ldots \ldots \ldots Equ(4.17)$$

Where y is the dependent variable in the model, x is the set of independent variables for each group, μ_i is country-specific intercepts, $\gamma i,j$ and $\lambda_{i,j}$ reflect short term country-specific coefficients, $e_{i,t}$ is the error term in each cross-section, i represents the country in the panel and t represents the time period.

Taking the variables under investigation such as a log of carbon dioxide emission, total primary energy consumption, real gross domestic product per capita, population density and urbanization into consideration, the model above or equation (4.17) becomes:

$$LCO_{2i,t} = \sum_{j=1}^{p} \gamma_{i,j}\, LCO_{2i,t-j} + \sum_{j=0}^{q} \lambda_{i,j}\, LTPEC_{i,t-j} + \sum_{j=0}^{q} \delta_{i,j}\, LRGDPPC_{i,t-j} + \sum_{j=0}^{q} \theta_{i,j}\, LPD_{i,t-j} + \sum_{j=0}^{q} \sigma_{i,j}\, UR_{i,t-j} + \mu_i + e_{i,t} \ldots\ldots Equ(4.18)$$

Where, $LCO_{2,}$ LTPEC, LRGDPPC, LPD, and UR, respectively are the natural logarithm of carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita, population density and urbanization for each group. The coefficients $\gamma_{i,j}$, $\lambda_{i,j}$, $\delta_{i,j}$, $\theta_{i,j}$ *and* $\sigma_{i,j}$, respectively are the short-run elasticities and all other things are defined earlier.

Once the variables ($LCO_{2,}$ LTPEC, LRGDPPC, LPD, and UR) are proved to be co-integrated, then there exists long-run relationship and they move together over time. In this case, the co-integration regression based on the variables that trend or moves together, convey a long-term equilibrium relationship. However, in the short-run, there may be disequilibrium and the residual of the co-integration regression can be treated as the equilibrium error. To this end, the above ARDL (p, q) model is re-parameterized into the error correction model as follows. The detailed proof of re-parameterization is available in APPENDIX D in appendices part of the paper.

$$\Delta LCO_{2i,t} = \sum_{j=1}^{p-1} \gamma_{i,j}\, \Delta LCO_{2i,t-j} + \sum_{j=0}^{q-1} \lambda_{i,j}\, \Delta LTPEC_{i,t-j} + \sum_{j=0}^{q-1} \delta_{i,j}\, \Delta LRGDPPC_{i,t-j} + \sum_{j=0}^{q-1} \alpha_{i,j}\, \Delta LPD_{i,t-j} + \sum_{j=0}^{q-1} \sigma_{i,j} \Delta\, UR_{i,t-j} + \varphi_i [LCO_{2i,t-1} - \theta_{1i} LTPEC_{i,t-1} - \theta_{2i} LRGDPPC_{i,t-1} - \theta_{3i} LPD_{i,t-1} - \theta_{4i} UR_{i,t-1} - \theta_{0i}] + e_{i,t} \ldots\ldots Equ(4.19)$$

Where, $LCO_{2i,t}, LTPEC_{i,t}$, $LRGDPPC_{i,t}, LPD_{i,t}$ *and* $UR_{i,t}$ respectively are the natural logarithm of carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita and population density and urbanization rate for country i at time t. The term in the square brackets contains the long-run regression. $e_{i,t}$ is the cross-section specific error terms or error terms in each cross section. The coefficients $\theta_{1i}, \theta_{2i}, \theta_{3i}$ *and* θ_{4i}, respectively capture the long-term relationship between the variables while the coefficients of the differenced variables $\gamma_{i,j}, \lambda_{i,j,}\, \delta_{i,j},\ \alpha_{i,j}, \sigma_{i,j}$ capture the short run relationship. $\varphi_i = -(1 - \rho i)$, is an error correcting term. This term tells the speed of adjustment coefficient which shows the speed at which the variables ($LCO_2, LTPEC\ , LRGDPPC, LPD\ and\ UR$) come back to the long-run equilibrium, once they are out of their equilibrium relationship or they found at any disequilibrium. The coefficient of error correcting term is expected to be statistically significant and have a negative sign. A statistically significant and negative error correcting term coefficient proves that there is evidence of a long run relationship between $LCO_2, LTPEC\ , LRGDPPC, LPD\ and\ UR$. In other words, once these conditions are fulfilled, there is also evidence of co-integration between the variables under investigation.

On the other hand, a positive coefficient of the error correcting term shows an opportunity that the variables under investigation may not come back to its long-run equilibrium relationship or the variables are not co-integrated. Further, the larger value of error correcting term coefficient indicates that the response of the variables to the previous period deviation from the long run equilibrium or from any disequilibrium is stronger and faster and vice versa.

4.5.4 Optimal Lags Selection

Before going to estimate the model, the appropriate lag order should be selected for the model specified above. Optimal Lag order selection in the panel ARDL model can be performed with different methods such as Akaike Information Criteria (AIC) and Schwarz-Bayesian Information Criteria (SBIC). Therefore, in order to choose the optimal lags for the model variables, an automatic grid search based on the minimization of Schwarz-Bayesian Information Criteria was conducted.

4.5.5 Alternative Estimation Methods

Once the optimal lags for the variables are specified, then one can estimate the model specified above. There are various methods to estimate the above re-parameterized Panel ARDL (p, q, q, q, q) model. These include the mean group (MG), pooled mean group (PMG) and dynamic fixed effects (DFE) estimation method. Therefore, equation (4.19) can be estimated using these three different estimators: namely the mean group (MG) model of Pesaran and Smith (1995), the pooled mean group (PMG) estimator developed by Pesaran et al. (1999), and the dynamic fixed effects estimator (DFE). According to Demetriades and Law (2006), all three estimators consider the long-run equilibrium and the heterogeneity of the dynamic adjustment process and are computed by maximum likelihood.

4.5.5.1 Mean Group (MG) Estimator

On one extreme, the less restrictive estimator is the mean group estimator which was first proposed by Pesaran and Smith (1995). Its main characteristics are: - First, mean group estimator does not impose any restriction on the model's slope parameters. Thus, it is the least restrictive of all the three estimators of panel ARDL modeling framework. Both the short and long-run parameters are allowed to be varying or differ across the country in the panel. The long-run slope coefficients and the short-run slope coefficients, intercepts, the error correcting term or the speed of adjustment to the long run equilibrium state and the error variances are assumed to be heterogeneous to the country to country in the panel. Second, of particular interest of the mean group estimator is the mean of the estimates, because it produces consistent estimates of the average of the parameters (calculates the coefficient mean) by averaging the data. This means mean group estimator estimate group-specific regression or regression for each country in the panel and after that calculates the coefficients as un-weighted means of the estimated coefficients for the individual countries. In the same token, in this estimator, the model is fitted for each group/country in the panel separately and the coefficients are averaged. However, according to Pearan et al (1997), mean group estimator does not capture the fact that some/ certain parameters might be the same or homogeneous across cross-section/country/group.

4.5.5.2 Pooled Mean Group (PMG) Estimator

The pooled mean group estimator was first introduced by Pesaran, Shin, and Smith (1999). The main characteristics of this estimator are: First, pooled mean group estimator is found in the middle of dynamic fixed effects and mean group estimators. In other words, pooled mean group estimator is an intermediate estimator between dynamic fixed effect and mean group estimators. Second, it is an intermediate estimator because it involves both pooling (dynamic fixed effects) and averaging (mean group). The pooled mean group estimator constrains the long- run slope coefficients to be homogenous across countries in the panel. Third, it however, allows the intercepts, short-run coefficients, and error variances to be varying or differ freely across groups in the panel. In other words, this estimator assumes country-specific short-run parameter that includes intercepts, the error correction terms to the long run equilibrium states and the error variances. Finally, this estimator provides consistent estimates of the mean of short-run coefficients by taking the simple average of the group/country specific coefficients.

4.5.5.3 Dynamic Fixed Effects (DFE) estimator

On the other extreme of the mean group estimator, the most restrictive estimator among the three is the dynamic fixed effects estimator. Similar to the pooled mean group or contrary to mean group estimators, dynamic fixed effects estimator constrains the long-run slope coefficients to be homogenous or the same across cross section/group/country. But, contrary to both mean group and pooled mean group estimators, this estimator further restricts the short-run slope coefficients, the error correcting term/speed of adjustment to the long run equilibrium state and error variance to be homogenous across cross section/group/country. Thus, this estimator allows only the intercept term to vary across cross section/group/country.

4.5.6 Selection among the three estimators

Once the model in equation (4.19) is estimated using the three alternative estimators, namely, mean group (MG), dynamic fixed effects (DFE) and pooled mean group (PMG) estimators, Hausman (1978) test is employed to test the efficiency of these estimators and to select among them. The efficiency test is performed to test the null hypothesis of slope homogeneity restriction. In this case, the estimators that impose homogenous slope coefficients across cross section/group/country outperform or dominate the estimator that imposes slope heterogeneity in terms of efficiency if and only if their assumption of slope homogeneity restriction is valid. Unless the restriction is valid, the estimators that restrict the slope coefficients are inconsistent. If the long-run homogeneity restriction is proved to hold, the pooled mean group estimator yields consistent and more efficient estimates compared to mean group estimator which imposes slope heterogeneity in both short and long-run. However, if the test proves that the long- run slope homogeneity restriction is not valid, the pooled mean group estimator becomes inconsistent, indicating the mean group estimator that assumes slope heterogeneity is consistent.

Generally, the mean group (MG) estimator produces consistent estimates of the mean of the long run coefficients, but its estimates will be inefficient when the slope homogeneity holds. Under the assumption of long-run slope homogeneity, the pooled mean group estimator produces consistent and efficient estimates of the model.

The test procedure is as follows:

First, formulate the hypothesis of the test.

The null hypothesis is: H_0= MG=PMG, indicates the MG and PMG estimator are not significantly different. This implies the PMG estimates are more efficient.

The alternative hypothesis is: H_1= MG ≠ PMG, this indicates the null is not true.

Second, perform the Hausman (1978) and obtain the probability value. Third, compare the probability value obtained from the second step with 5 % percent level of significance or the conventional level of significance. The guideline is:

Use pooled mean group estimator when the probability value (P-value) from Hausman (1978) test is greater than the conventional level of significance (5 %). If P-value > 0.05, pooled mean group estimates are consistent and more efficient than mean group estimates. In other words, if this condition holds, the null hypothesis of slope homogeneity cannot be rejected.

Use mean group estimator when the probability value (P-value) from Hausman (1978) test is less than the conventional level of significance (5%). If P-value < 0.05, mean group estimates are consistent and more efficient than pooled mean group estimates. In other words, if this condition holds, the null hypothesis of slope homogeneity can be rejected.

The same procedure can be performed in order to test between mean group (MG) and dynamic fixed effects (DFE) estimators. The null is the same because it also states the slope homogeneity assumption. If the slope homogeneity assumption holds, dynamic fixed effect (DEF) estimates are consistent and more efficient than mean group (MG) estimator. However, if the null of slope homogeneity does not hold, mean group (MG) estimator outperforms the dynamic fixed effect (DFE) estimator.

Generally, under the alternative hypothesis of the Hausman (1978) test, the estimators that impose slope homogeneity assumption are inconsistent and mean group (MG) estimator outperforms both pooled mean group (PMG) and dynamic fixed effects (DFE) estimator. However, under the null of slope homogeneity, both pooled mean group (PMG) and dynamic fixed effects (DFE) estimators outperform mean group (MG) estimator.

However, the question here is whether the Hausman (1978) test can be applied to compare the pooled mean group (PMG) and the dynamic fixed effects (DFE) estimators in which both impose the long-run slope homogeneity restriction. Once the Hausman (1978) test conducted confirms the pooled mean group (PMG) and dynamic fixed effects (DFE) estimators are both efficient and preferred to the MG estimator, this leads to the question of comparison between pooled mean group (PMG) and dynamic fixed effects (DFE) estimators. However, according to Pesaran et al(1997, 1999), pooled mean group (PMG) estimator is advantageous than dynamic fixed effects (DFE) estimator in that it provides country-specific short-run dynamic slope coefficients, while the long-run slope coefficients are the same for all country as in the case of (DFE). In other words, pooled mean group (PMG) estimator is more advantageous than dynamic fixed effects (DFE) in its flexibility in the short run coefficients across cross section/group/country. However, dynamic fixed effects (DFE) produce the estimates of the panel ARDL techniques by assuming the data in the multiple countries is pooled as a single entity or country. This implies each of the regressors in the model has a common slope coefficient both in the short and long run. Thus, the assumption of common short-run slope coefficients among the countries in the sample is less compelling with the evidence of the rate of growth of technology as well as economic activity varied across countries.

Following this argument, some articles conducted previously did not utilized a Hausman test to compare between pooled mean group (PMG) and dynamic fixed effects (DFE) estimators. These papers include Pesaran, Shin, and Smith (1997, 1999), that provide two empirical applications: aggregate consumption functions for 24 Organization for Economic Cooperation and Development(OECD) countries over the period 1962-1993, and energy demand functions for 10 Asian developing countries over the period 1974-1990. These two examples of empirical application in their article introduced the pooled mean group (PMG) estimator, neither of them by performing a Hausman test of the pooled mean group (PMG) versus dynamic fixed effects (DFE). Their arguments for this is, pooled mean group (PMG) estimator is more advantageous than dynamic fixed effects (DFE) in its flexibility in the short run coefficients across cross section/group/country. In other words, the most important advantage of the PMG over the traditional DFE model is that it can allow the short-run dynamic coefficients to differ from country to country.

Further, from the statistical intuition, the pooled mean group (PMG) estimator produces more precise estimates of long-run coefficients than dynamic fixed effects (DFE) estimator, because pooled mean group (PMG) estimators provide substantially smaller standard errors of the long run coefficients compared to dynamic fixed effects (DFE) estimator (Pesaran et al, 1997; 1999).

Accordingly, given the intuitions provided by the pooled mean group (PMG) estimator, the pooled mean group (PMG) estimator is preferred over dynamic fixed effects (DFE) estimator in the present study analytical framework. Such preference is basically the homogeneity assumption in the long-run might be linked with the remote objective of the countries under study to reduce the level of anthropogenic emissions of carbon dioxide via adopting the common technologies that alters the growth of carbon dioxide in the atmosphere, including promotion/adoption/ of environmentally friendly growth policy and also clean energy alternatives such as hydro, solar and wind. But in the short-run, the assumption of common short-run slope coefficients among the countries in the sample is less compelling with the evidence of the rate of growth of technology as well as economic activity, rate of adopting the common technology varied across countries. Given this, the present study conducted Hausman (1978) test to confirm the long-run homogeneity assumption, but not to compare between pooled mean group (PMG) and dynamic fixed effects (DFE) estimators.

4.5.7 Validity, Efficiency, Consistency issue and Diagnostic tests of panel-ARDL

There are a number of issues that should be satisfied for the validity, consistency, and efficiency of the estimates from the panel ARDL technique. These include:

- The time dimension of the cross-section (T): the estimates of the panel ARDL technique to be valid, consistent and efficient, the time dimension (T) has to be long enough in order to estimate the model for each cross section/country separately. To satisfy this condition the present study accounts the only countries at least 29 consecutive observations are available.

- Co-integration among the model variables: the existence of the long-run equilibrium relationship or co-integration among the model variables needs the coefficient on the error correction term should be statistically significant and have a negative sign, and further should not be lower than -2.
- Serial correlation among the error terms and exogenity of the regressors: the estimates of the panel ARDL technique to be valid, consistent and efficient, the residuals resulted from the panel error correction model should be serially uncorrelated and the regressors should also be exogenous. This condition can be satisfied by augmenting the model with the appropriate lag length or can be fulfilled by including the ARDL (p, q, q, q, q) for carbon emissions, total primary energy consumption, real gross domestic product per capita, population density and urbanization, respectively in the error correction form. To this end, the present study augmented the panel ARDL model by selecting appropriate optimal lags using (SBIC). This study also conducts some of the diagnostic tests regarding the selected panel ARDL (p, q, q, q, q). However, such diagnostic tests were conducted not in panel level, but in the country level. In fact, none of the articles that the researcher comes across perform diagnostic tests for the panel ARDL estimation, except Pesaran et al (1997; 1999) and Anne, K. F (2013), which conducted country-specific diagnostic tests for the selected panel ARDL model before going to the estimation of the model and compare the result among the countries in the sample. Therefore, following studies, the present study conducted diagnostic tests for the selected panel ARDL model to ensure that the panel is fine and no misspecification.
- Cross-sectional dependence: the estimator of the panel ARDL technique assumes the cross-sectional independence of the residual $(e_{i,t})$ resulting from the regression model. In the panel data setting the cross-sectional dependence to arise from omitted common effects which simultaneously affect all the groups in the panel. Such cross-sectional dependence affects the ARDL estimations and results in misspecifications. However, Pesaran et, al (1997; 1999) provide alternative measures to eliminate such common factors that affect the estimation result and causes misspecification of the model. These measures include: First, include the cross-sectional averages of the included explanatory variables as additional regressors in the model. Second, use all of the variables as deviations from their respective cross-sectional means in each period. Therefore, to this

end, the present study utilized the second procedure to eliminate the common factors. In order to confirm that the common factor that affects the panel simultaneously and causes misspecification is eliminated using demeaned data, the present study conducted the cross-sectional dependence tests for the residuals obtained from the model estimated.

4.5.8 Causality test

A Granger causality test is made to the selected Panel-ARDL (1, 1, 1, 1, 1) model to identify the direction of causality between the dependent variable (carbon dioxide emission) and the independent variables (total primary energy consumption, real per capita GDP, population density and urbanization). That is a pairwise Granger causality test is applied to the selected model to know the direction of causality of carbon dioxide emission with the model explanatory variables listed above.

CHAPTER FIVE

EMPIRICAL RESULTS AND DISCUSSIONS

5.1 Introduction

This chapter is devoted to the results and analysis and discussion of the data. It presents the correlation, multi-col-linearity, stationarity and co-integration properties (or nature) of the variables under investigation. In addition, the chapter presents the long- run and short-run estimates of the alternative estimators. Further, it presents the Hausman (1978) test result which is used to select consistent and efficient estimators to be interpreted and discussed. Finally, diagnostic tests are also discussed.

5.2 Multi-col-linearity issue of the data

In order to test whether the data exhibits the multi-col-linearity problem, the study utilized the correlation matrix and variance inflation factor among explanatory variables of the model. Multi-col-linearity is a state of very high inter-correlations or inter-associations among the independent variables. If high inter-correlation exists in the independent variables of the estimated model, the result may be individually unstable and insignificant but jointly significant. Give this; the present study employed two methods that detect the presence of multi-col-linearity in the data. In this study, the multi-col-linearity test is conducted both by country and panel in order to compare the behavior of the data by country as well as panel level. Such comparison is helpful to discuss the advantage of panel data analysis over simple time series data analysis. One advantage of panel data is related to col-linearity issue among the independent variables. In this context panel data is advantageous by making the data less col-linear (Marques et al, 2010).

According to Goldberger (1991), multi-col-linearity is basically a problem of the absence of enough data points. Hence, the use of panel data increases the total number of observation or eliminates the problem of not enough data and reduces the disturbance power of multi-col-linearity. If this is the case, the multi-col-linearity is not a serious problem in the panel data analysis and it can be disregarded (Gujarati, 2009). According to Marques et al (2010), panel data allows greater variability in the data, less col-linearity among the variables, a larger degree of freedom, and provides more information and efficiency in the estimates. Given this, if a different country time series data form a time series of cross-section (panel data), the multi-col-linearity among the variables become less and not that much a problem, despite it might be a problem or not by country due to a shortage of data or other factors. Therefore, the results of both country-specific and panel level multi-col-linearity tests are reported in Table 5.1 and 5.2 in APPENDIX E.

As it can be observed from Table 5.1 and 5.2 in APPENDIX E, the result of the multi-co-linearity test confirmed the argument above that panel data provide less col-linearity in the data. The country-specific multi-col-linearity test result provides mixed evidence. The result shows that multi-col-linearity in the data is not problematic in Burundi, Comoros, Ethiopia, Malawi, Rwanda, Zambia and Zimbabwe case. However, in the remaining seven countries it is found to be problematic. To be noted multi-col-linearity in the data is more problematic in Tanzania followed by Uganda. This is might be due to the argument that insufficient data points results in high col-linearity since both Tanzania and Uganda in that order have the shortest data points compared to other countries under consideration.

Panel multi-col-linearity test results in Table 5.2 confirmed multi-col-linearity is not problematic in the data. Accordingly, there is no exact linear combination of one another among total primary energy consumption, real gross domestic product per capita, population density and urbanization in the time series of the cross-section (or panel data). From this, one can understand that panel data are more advantageous than simple time series data because it allows less col-linearity in the data.

5.3 Panel unit root test results

As clearly pointed out under methodology, particularly under estimation procedure part in Chapter 4, the first step is to ascertain the stationarity properties of the variables in the model in order to avoid the problem of spurious regression and inappropriate estimation and inference.

The present study, tests for unit root to see whether the model variables are integrated of order two or I (2) because panel ARDL specification doesn't require unit root pre-testing of the variables since it can be estimated regardless of whether the model variables are I (0) or I (1) or fractionally integrated. Therefore, to determine this condition, panel unit root examined using standard panel unit root tests that can handle unbalanced panel data. The panel unit root tests that can accommodate unbalanced panel including Im, Pesaran, and Shin (2003), which is abbreviated as IPS test, and the two Fisher- type tests such as Fisher-ADF and Fisher-PP tests are employed. For all these tests, the null hypothesis is that there is a unit root or the variable is non-stationary and the alternative hypothesis is that there is no unit root or the variable is stationary.

Accepting or rejecting the null hypothesis depends on P values. When the P-Value is smaller than the standard significance levels 1%, 5%, and 10%, we reject the null hypothesis. In order to standardize the test for unit root and co-integration, the present study assumes that the test regressions contain only intercept because Kao (1999) panel co-integration test only assume an intercept in the regression. In other words, to make the result of panel unit root and co-integration tests consistent by assumption, the model assume only intercept in all the three-panel unit root as well as co-integration tests, the reason of which is because Kao (1999) panel co-integration test captures the equation with the only intercept. Further, the numbers of lags are selected automatically using the Schwarz Bayesian information criterion (SBIC).

Accordingly, panel unit root tests are utilized in order to analyze the stationarity properties of the variables under investigation even though the panel ARDL model doesn’t require pre-testing of the variables for stationarity. Unit root test that presents the order of integration of the variables under investigation is highlighted in table 5.3 below

Table 5.3 reports the results of panel unit root tests of the variables under consideration. As can be observed from the IPS unit root test in the first column of the table, all the variables in the model are stationary at a 1% level of significance. Further, urban population growth or urbanization is found to be stationary at a level in at 1% level of significance. Therefore, the results of the IPS panel unit root test confirmed that none of the variables are stationary in the second difference or I (2).

Similarly, the Fisher-ADF and PP tests indicate that none of the variables under investigation are integrated of order two (see column two and three of the table). Similar to IPS test results, Fisher-ADF and Fisher-PP type of panel unit root test results indicate carbon dioxide emissions, real gross domestic product per capita and total primary energy consumption are stationary at their first difference at 1% level of significance. However, unlike IPS tests result, the results from Fisher-ADF and Fisher-PP tests show population density is stationary at level. Further, urbanization also found to be level stationary series.

Table.5.3. Panel unit root tests result of the model variables

Variables	IPS, Fisher-ADF and Fisher-PP tests					
	IPS		Fisher-ADF		Fisher-PP	
	Statistics	P-value	Statistics	P-value	Statistics	P-value
LCO_2	2.95672	0.9984	28.9927	0.4129	6.30139	1.0000
$D(LCO_2)$	-15.6331***	0.0000	255.316***	0.0000	307.230***	0.0000
LTPEC	4.23610	1.0000	19.9024	0.8680	30.1730	0.3550
D(LTPEC)	-20.1760***	0.0000	332.213***	0.0000	398.067***	0.0000
LRGDPPC	4.91395	1.0000	18.6252	0.9556	14.2790	0.9851
D(LRGDPPC)	-13.3625***	0.0000	215.976***	0.0000	229.293***	0.0000
LPD	3.47719	0.9997	38.5459*	0.0538	85.2728***	0.0000
D(LPD)	-8.77554***	0.0000	152.093***	0.0000	87.7579***	0.0000
UR	-2.80313***	0.0025	58.9005***	0.0006	55.1750***	0.0016
D(UR)	-17.2477***	0.0000	267.631***	0.0000	253.689***	0.0000

Note: ***, ** and * indicate the rejection of a null hypothesis of non-stationary at 1%, 5% and 10% level of significance, respectively. All unit root tests are conducted with intercept. P-values are listed in the open bracket. Automatic lag length selection is based on SBIC (Schwarz Bayesian information criteria). LCO2, LTPEC, LRGDPPC, LPD and UR are natural logarithm of carbon emissions proxied by carbon dioxide emissions from fossil fuel, total primary energy consumption, real gross domestic product per capita, population density and urbanization proxied by annual urban population growth, respectively whereas D(LCO2), D(LTPEC), D(LRGDPPC), D(LPD) and D(UR) indicates their first difference.
Source: Own Estimation using Eviews 9.0

From Table 5.3, one can conclude that none of the variables are I(2), which is a precondition for applying the panel-ARDL model. In other words, all the three tests revealed that the model has variables that are fractionally integrated or are I(1) or I(0), none of the variables are found to be integrated of order two. Therefore, this condition makes the panel-ARDL model the appropriate to conduct long-run relationship analysis among variables under investigation.

5.4 Panel co-integration test results

Once the stationarity properties of the variables under investigation are ascertained or checked, one can proceed to test the long-run relationship or co-integration among the variables under investigation using standard panel co-integration tests and Wald-test of long-run coefficients restriction. In addition to these, the long-run relationship can also be ascertained using the statistical significance of the error-correction term as it clearly discussed in the methodology part of the paper. Therefore, the Kao (1999) residual-based co-integration test result of the variables is reported in Table 5.4 below whereas Wald- test is performed after the lags order of the variables under investigation is specified. This is because it requires the estimation of the model using the length of the optimal lags. Table.5.4 reports the Kao (1999) panel co-integration tests result.

Table.5.4: Kao (1999) panel co-integration test result of the model variables

Kao (1999) co-integration test			
Model	ADF	t-statistic	P-values
LCO_2, LTPEC, LRGDPPC, LPD, UR		-3.506663	0.0002***

Note: *** indicates the rejection of a null hypothesis of no-co-integration at a 1% level of significance. Null hypothesis: No co-integration. Trend assumption: no deterministic trend. Automatic lag length selection is based on SBIC (Schwarz Bayesian information criteria).
Source: Own Estimation using Eviews 9.0

The null hypothesis of the test claims there is no long-run relationship between the variables under investigation, while the alternative is the opposite. As can be observed from the table, the P-value of the test is found to highly statistically significant (1% level of significance). Accordingly, the null hypothesis of no long-run relationship among the variables under study is rejected. Therefore, the existence of a long-run relationship between the variables such as carbon dioxide emission, total primary energy consumption, real gross domestic product per capita, population density, and urbanization is confirmed.

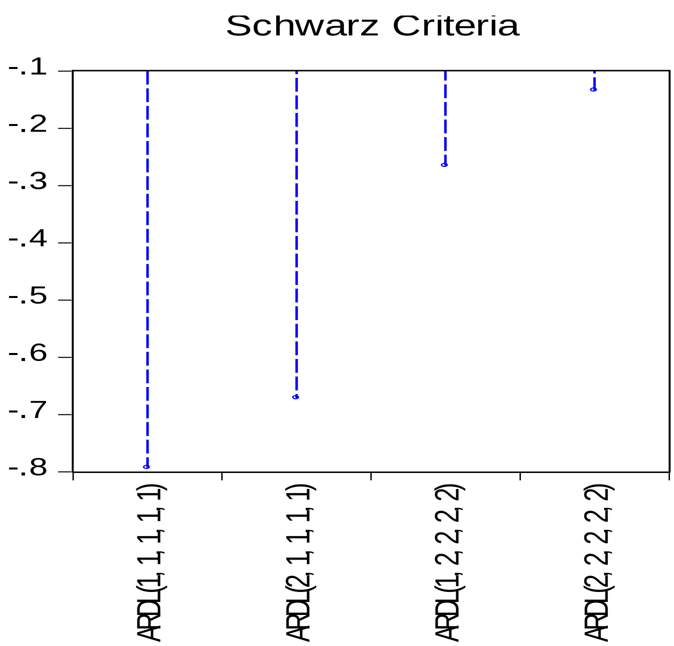
5.5 Optimal lags selection

In order to select the length of the optimal lags for the variables under investigation in the panel-ARDL model, the present study utilized Schwarz Bayesian information criteria (SBIC). According to Pesaran and shin (1999), for the annual data, a maximum of two lags length is recommended to choose the optimal lag for each variable under consideration. Therefore, a maximum of two lag lengths is chosen for the conditional panel-ARDL model and finally SBIC automatically selects the optimal lag length of each variable such as LCO_2, LTPEC, LRGPPPC, LPD, and UR, respectively to be 1 and the model becomes a Panel-ARDL (1, 1, 1, 1, 1). This automatic determination of the lag length for the variables is to get the valid results and inferences.

5.5.1 Measuring the strength of the model selected

This study utilized the criteria graph, in order to see the strength of the model selected using the standard model selection criteria. The determination of the strength of the model selected is based on the benchmark analysis: the lower the value of the standard model selection criteria, the better/stronger the model selected. Therefore, the strength of the selected model is highlighted in Figure 5.1. As can be observed from the figure, the first panel-ARDL (1, 1, 1, 1, 1) model is stronger than other three panel-ARDL models and strongly preferred than those three because the associated value of the SBIC is the lowest or the most negative compared to the remaining three models in the graph. However, the second top model is panel-ARDL (2, 1, 1, 1, 1) according to the criteria graph.

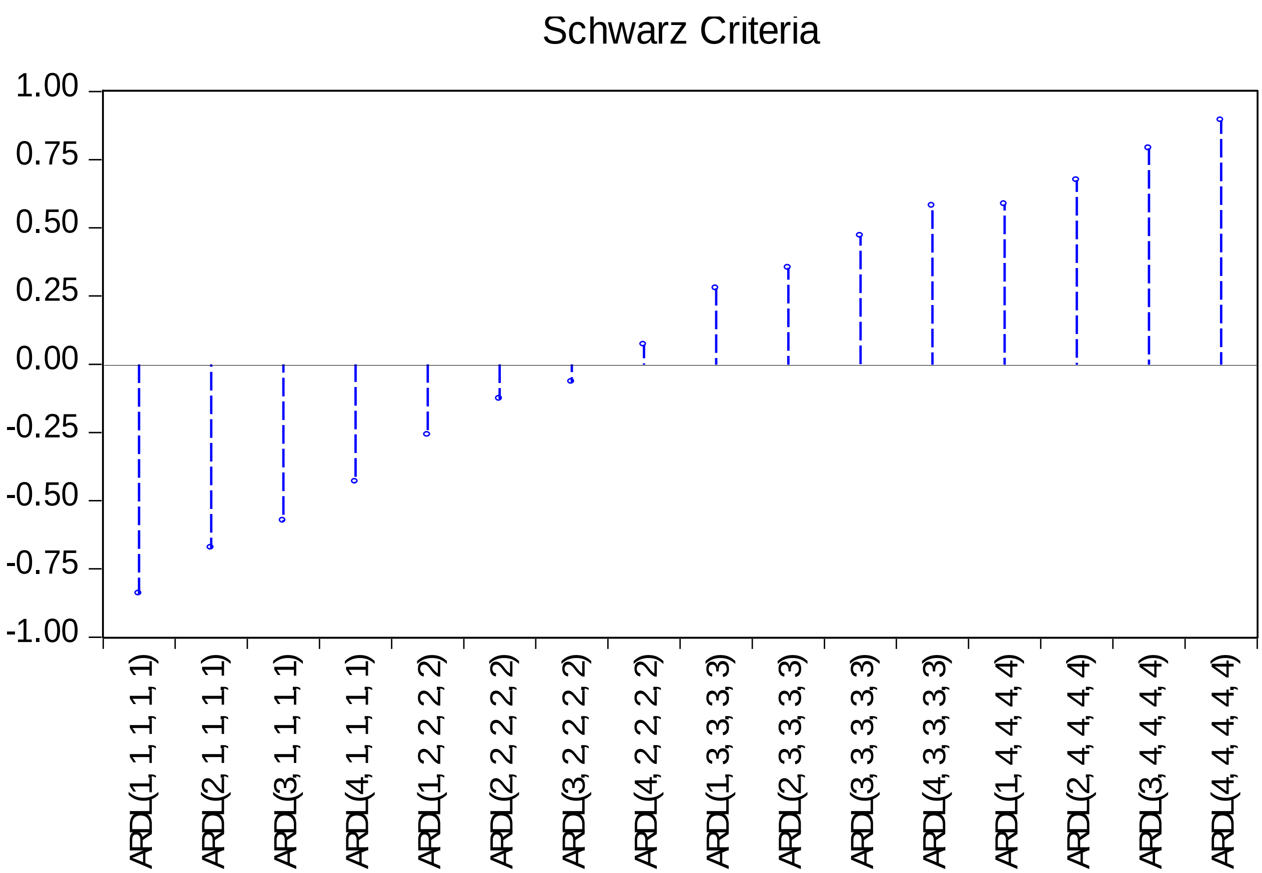
Figure 5.1: Optimal lag length for the variables using SBIC with a maximum of two lags



Source: own computation using Eviews 9.0

Further, when the recommendation of the Pesaran and Shin(1999) is relaxed and 4 lags are imposed for each variable in the conditional panel-ARDL model, SBIC automatically provides a similar or consistent result with the case of Pesaran and Shin(1999) recommendation of two lags(see figure 5.2). However, in this case, the number of top models to compare increased to 16, but in the first case, SBIC compares only 4 top models. Similar to the top 4 models case, in the top 16 models case the value of SBIC is the lowest or the most negative value is accounted with the panel-ARDL (1, 1, 1, 1, 1) model. Therefore, the present study utilized panel-ARDL (1, 1, 1, 1, 1) model for LCO_2, LTPEC, LRGDPPC, LPD, and UR, respectively in order to estimate the dynamic long run and short-run relationship between the variables under investigation.

Figure 5.2: Optimal lag length for each variable using SBIC with a maximum of four lags



Source: own computation using Eviews 9.0

5.6 Panel ARDL (1, 1, 1, 1, 1) Estimation Results

After determination of the optimal lags length for each variable under investigation, the next most important is estimating the dynamic long-run and short-run coefficients of the panel-ARDL (1, 1, 1, 1, 1) model by utilizing the three alternative panel-ARDL estimators such as Mean Group (MG), Pooled Mean Group (PMG) and Dynamic Fixed Effects (DFE) estimators. This step involves the estimation of the slope coefficients (both the short and long–run) of the model. The estimation results are reported in Table 5.5:

Table 5.5: Panel-ARDL dynamic regression for the short and long run estimates

Table 5.5a Mean Group (MG) estimation result

Dependent variable: D(LCO_2)

Method: Panel-ARDL

Model selection criteria: SBIC

Selected model: Panel-ARDL (1, 1, 1, 1, 1)

Estimator: Mean Group (MG)

Variable	Coefficient	Standard error	t-statistics	P-values
Long-run coefficients				
LTPEC	.4831768	.2785706	1.73	0.083*
LRGDPPC	.501873	.4677176	1.07	0.283
LPD	2.411013	1.919297	1.26	0.209
UR	-.4182131	.5128944	-0.82	0.415
Short-run coefficients				
D(LTPEC)	.1062986	.0624658	1.70	0.089*
D(LRGDPPC)	.2568709	.1169398	2.20	0.028**
D(LPD)	-8.159993	10.50575	-0.78	0.437
D(UR)	-.0116549	.0136908	-0.85	0.395
ECT_{-1}	-.4516984	.0600514	-7.52	0.0000***
C	.3749508	.2189243	1.71	0.087*

Note: ***, **and * indicate the rejection of a null hypothesis of statistical insignificance of the coefficients at 1%, 5% and 10% level of significance.
Source: Own Estimation using STATA 13.0

Table 5.5b Pooled Mean Group (PMG) estimation result

Dependent variable: D(LCO_2)

Method: Panel-ARDL

Model selection criteria: SBIC

Selected model: Panel-ARDL (1, 1, 1, 1, 1)

Estimator: Pooled Mean Group (PMG)

Variable	Coefficient	Standard error	t-statistics	P-values
Long-run coefficients				
LTPEC	.9209388	.0868187	10.61	0.000***
LRGDPPC	.3548048	.1207925	2.94	0.003***
LPD	.2377611	.1260457	1.89	0.059*
UR	.1137519	.0255648	4.45	0.000***
Short-run coefficients				
D(LTPEC)	.2100188	.0777958	2.70	0.007***
D(LRGDPPC)	.2247178	.1003338	2.24	0.025**
D(LPD)	.1658011	2.459899	0.07	0.946
D(UR)	-.0285118	.0172671	-1.65	0.099*
ECT_{-1}	-.2588951	.0630549	-4.11	0.000***
C	.0190305	.0670121	0.28	0.776
Log Likelihood = 468.8953				

Note: ***, ** and * indicate the rejection of a null hypothesis of statistical insignificance of the coefficients at 1%, 5% and 10% level of significance.
Source: Own Estimation using Eviews 9.0 and STATA 13.0

Table 5.5c Dynamic Fixed Effects (DFE) estimation result

Dependent variable: D(LCO_2)
Method: Panel-ARDL
Model selection criteria: SBIC
Selected model: Panel-ARDL (1, 1, 1, 1, 1)
Estimator: Dynamic Fixed Effects (DFE)

Variable	Coefficient	Standard error	t-statistics	P-values
Long-run coefficients				
LTPEC	.3772277	.1422541	2.65	0.008***
LRGDPPC	.707031	.2154947	3.28	0.001***
LPD	.9719006	.2181754	4.45	0.000***
UR	.0626274	.0249763	2.51	0.012**
Short-run coefficients				
D(LTPEC)	.2149785	.0346679	6.20	0.000***
D(RGDPPC)	.1374759	.0991644	1.39	0.166
D(LPD)	-.171747	.3034627	-0.57	0.571
D(UR)	.0045939	.0060668	0.76	0.449
ECT_{-1}	-.1492751	.0220895	-6.76	0.000***
C	.0229529	.0093656	2.45	0.014**

Note: *** and ** indicate the rejection of a null hypothesis of statistical insignificance of the coefficients at 1% and 5% level of significance.
Source: Own Estimation using STATA 13.0

The tables 5.5a, 5.5b and 5.5c provide three alternative estimates obtained from Mean Group (MG) which impose any restriction in both short-run and long-run coefficients, Pooled Mean Group (PMG) which impose common long-run coefficients but allows the short-run coefficients including the speed of adjustment to the long-run state of equilibrium to vary or be heterogeneous across the cross-section under consideration and Dynamic Fixed Effects (DFE) which impose restrictions in all slope coefficients (both the short-run and long-run) and also the speed of adjustment term, respectively.

The long-run coefficients: as can be seen from the three alternative estimator's results**,** the coefficients exhibit different statistical significances. From table 5.5a, mean group (MG) provides the least insight on the long-coefficients or determinants of carbon dioxide emissions compared to pooled mean group (PMG) and dynamic fixed effects (DFE) estimators. This is observed from its long-run coefficients, the result of which show that all of the long-run coefficients are statistically insignificant at 5% level of significance. However, the coefficient of total primary energy consumption is statistically significant at 10% level and its sign is in line with the study's expectation which is positive. Form MG long-run estimates, the coefficients of population density and real gross domestic product per capita are statistically insignificant. On the other hand, from pooled mean group (PMG) estimation results (Table 5.5b), three of the four long-run coefficients are statistically significant at 1% level of significance. These are the coefficients of total primary energy consumption, real gross domestic product per capita and urbanization. The other coefficient, the coefficient of population density is statistically significant at 10 % level of significance.

Generally, the long-run coefficients of the pooled mean group (PMG) estimator are statistically significant and also their sign exhibits the study's expectation. From the dynamic fixed effects (DFE) estimation results (Table 5.5c), one can observe that all of the long-run coefficients are statistically significant at 1% level of significance except urbanization which is statistically significant at 5% level of significance. The signs of the coefficients are also in line with the signs of the PMG long-run coefficients and also the study's expectation.

The short-run coefficients: going back to the short-run coefficients of the three alternative estimators, coefficients still exhibit different statistical significances as well as signs. The results of mean group (MG) estimation shows two of the four short-run coefficients; that is, the coefficient of total primary energy consumption is statistically significant at 10% level and the coefficient of the log of real gross domestic product per capita is statistically significant at 5% level. These coefficients also fulfill the study's expectation in their signs. However, the coefficients of population density and urbanization are statistically insignificant.

On the other hand, from the pooled mean group (PMG) estimation results, all the short-run coefficients of the variables are statistically significant except for the coefficient of population density. Among these coefficients, the coefficients of total primary energy consumption and real gross domestic product per capita are statistically significant at 5% level and also exhibit the study's expected sign, and the coefficient of urbanization is statistically significant at 10% level but failed to exhibits the expected sign of the study.

The result from the dynamic fixed effects (DFE) estimation indicates that all the short-run coefficients are statistically insignificant except for the coefficient of the total primary energy consumption but its sign in line with the study's expectation. The short-run coefficients of the real gross domestic product per capita and urbanization exhibits the study's expected sign, despite they are insignificant statistically.

Error-correction term: as it can be observed from the results of the three alternative panel-ARDL model estimators, the error-correction term is highly statistically significant at 1% level of significance. The sign of the coefficients of the error-correction/speed of adjustment/ term is also in line with the study's expectation. According to Pesaran et al (1999), the existence of the long-run relationship between the variables under consideration can be inferred from the statistically significant negative error-correction/speed of adjustment/ term coefficient. In other words, the error-correction term has to be negative and greater than negative two (-2) for the confirmation of the long-run relationship.

In the present study, the coefficient of the error-correction term is negative and greater than -2 and also statistically significant at 1% level of significance in all of the three alternative estimators of the panel-ARDL (1, 1, 1, 1, 1) model. Therefore, the estimates or the coefficients of the error correction term rejects the null hypothesis of no long-run relationship among carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita, population density and urbanization. This conclusion confirms the result of the standard panel co-integration (Kao (1999) test above, which suggested the long-run relationship among the variables under investigation.

5.7 Hausman test

In this study, the Hausman (1978) test is utilized in order to test the null-hypothesis of slope homogeneity. As pointed out in the methodology part of the study, the mean group (MG) estimator is not imposes restriction in both the short-run and long-run coefficients. In this case, both the short and long-run coefficients, as well as the speed of adjustment to the long-run state of equilibrium, are heterogeneous among the cross-section under consideration. While pooled mean group (PMG) estimator imposes common long-run coefficients and allows the short-run coefficients including the speed of adjustment to the long-run state of equilibrium to vary or be heterogeneous across the cross-section under consideration. Further, the more restrictive estimator, dynamic fixed effects (DFE) imposes restrictions in all slope coefficients (both the short-run and long-run) and also the speed of adjustment term. This estimator constrains the long-run coefficients to be the same across the cross-section under consideration which is in line with PMG estimator. But contrary to PMG estimator, DFE restricts the short-run coefficients as well as the speed of adjustment to be the same across cross-section under study. The PMG estimator constrains the long-run coefficients to be the same across all cross-sections and provides consistent and efficient estimates when the restrictions are true. Once the true estimator is heterogeneous (MG), then the PMG result is inconsistent but MG estimator provides a consistent result. The same is true for MG and DFE. The present study used the Hausman (1978) test in order to test the difference among the model estimators (MG vs PMG and MG vs DFE).

This study didn't conduct the Hausman (1978) test to compare the PMG and DFE because PMG estimator is advantageous compared to DFE in that is allows the short run coefficients of the model to vary across cross-section (Pesaran et, al,1999), but DFE estimator provides the slope coefficients of the model by considering the panel as a single entity. However, in the short-run dynamics, the countries under investigation have different policies that impact the level of carbon dioxide emissions in each country. However, in the long-run, the common long-run objective of reducing the level of carbon dioxide emission among the countries under investigation might lead to the same impact of the total primary energy consumption, real gross domestic product per capita, population density and urbanization. This is because, in order to achieve the common objective of the countries which is reducing the level of carbon dioxide emissions resulting from human activities, the countries under analysis could come into a common consensus, adopt common technologies and act together in the long-run. However, in the short-run, any action to reduce the level of anthropogenic emissions of carbon dioxide is affected by the country-specific effects. Therefore, the present study takes PMG as the preferred model because it allows the short-run dynamics to be heterogeneous across the countries under investigation. Accordingly, the test of slope homogeneity is conducted as MG vs PMG and MG vs DFE. The results of the Hausman (1978) test are reported in table 5.6:

Table 5.6: Husman (1978) test of slope homogeneity (MG vs PMG and MG vs DFE)

```
. hausman mg pmg, sigmamore

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       mg          pmg         Difference          S.E.
-------------+----------------------------------------------------------------
        LENN |    .4831768     .9209388        -.437762        .3461282
        LGCC |     .501873     .3548048        .1470682        .5868461
        LPDD |    2.411013     .2377611        2.173252        2.455396
         URR |   -.4182131     .1137519        -.531965        .6565229
------------------------------------------------------------------------------
                          b = consistent under Ho and Ha; obtained from xtpmg
           B = inconsistent under Ha, efficient under Ho; obtained from xtpmg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        1.76
                Prob>chi2 =      0.7800

. hausman mg DFE, sigmamore

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       mg          DFE         Difference          S.E.
-------------+----------------------------------------------------------------
        LENN |    .4831768     .3772277        .1059491         3.90316
        LGCC |     .501873      .707031        -.205158        6.554181
        LPDD |    2.411013     .9719006        1.439112        26.90897
         URR |   -.4182131     .0626274       -.4808405        7.191089
------------------------------------------------------------------------------
                          b = consistent under Ho and Ha; obtained from xtpmg
           B = inconsistent under Ha, efficient under Ho; obtained from xtpmg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.01
                Prob>chi2 =      1.0000
```

Source: own calculation using Eviews 9.0

As it can be observed from Table 5.6, the P-value associated with the Hausman test for MG and PMG in the upper part of the table above is 0.78. The null hypothesis of the Hausman test is the long-run coefficients are homogenous across the cross-section. Given this, the test suggests the acceptance of the long-run slope homogeneity. The test confirms that the true estimator is homogenous long-run slope, which means the pooled mean group (PMG) estimates are consistent and efficient and the mean group(MG) estimates are inconsistent. Given this, the preferred estimation result is pooled mean group (PMG) estimates.

In order to support the above result of slope homogeneity, another test also carried out to test slope homogeneity between mean group (MG) and dynamic fixed effects (DFE) estimators. Therefore, the P-value associated with the Hausman test for MG and DFE in the lower part of the table above is one (1). This test strictly rejects the alternative hypothesis of slope heterogeneity. Therefore, the slope heterogeneity is rejected in both MG vs PMG and MG vs DFE tests. However, the comparison between PMG and DFE is not conducted because of the advantage of PMG estimates over DFE.

5.8 Model Diagnostics

Before going to interpret the result of the PMG estimator, the present study carried out some diagnostic tests to verify the viability and reliability of the estimates. These diagnostic tests include the Wald-test of a long-run relationship between variable under consideration using the PMG estimation result and the cross-sectional dependence test of the residual resulted from the PMG estimation result. Further, the study also carried out group-specific diagnostic tests such as serial correlation, heteroskedasticity, and normality of the residual for the selected ARDL (1, 1, 1, 1, 1) model, which is the time series version of panel-ARDL by country. In addition, the study also carried out the functional form of the model test by country under study.

5.8.1 Wald- test of a long-run relationship

Table 5.7 reports the results of long-run co-integration test obtained by Wald-test. As can be observed, the P-value of the F-statistic is highly statistically significant. Accordingly, the present study rejects the null hypothesis of no long-run relationship between the variables under consideration. In the panel-ARDL techniques of analysis, the critical values for the Wald- test of long-run relationship are not provided in the literature. This also confirms the evidence for the presence of a long-run relationship among the variables under investigation. This result supports the outcome of the standard panel co-integration (Kao (1999)) test discussed as well as the decision made using the statistical significance of the error-correction term above. Therefore, a significant and positive value of the computed F-statistics from Wald-test of panel-ARDL co-integration test infers a long-run relationship between carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita, population density, and urbanization.

Table 5.7 Wald-test of Panel-ARDL co-integration

Wald- test

Model: Panel-ARDL (1, 1, 1, 1, 1)

Test –statistics	Value	Df	P-values
F-statistics	414.8435	(4, 419)	0.0000***
Chi-square	1659.374	4	0.0000***

Note: *** indicates the rejection of a null hypothesis of no co-integration at 1% level of significance.
Source: Own Estimation using Eviews 9.0

Generally, the present study ascertained the existence of a long-run relationship between carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita, population density, and urbanization by utilizing the three important test of co-integration. These include, the standard residual based panel co-integration (Kao (1999)) test, the well-known panel-ARDL co-integration test, which is the statistical significance of the error-correction term and finally the Wald-test of the long-run coefficients restrictions. The entire three alternative co-integration test suggested evidence of the existence of the long-run relationship among the model variables.

5.8.2 Cross-sectional dependence test

In the panel data context, cross-sectional dependence arises from omitted common effects which simultaneously affect all the groups in the panel. Such cross-sectional dependence affects the model estimations and results in misspecifications. Pesaran, et al (1997; 1999) suggested measures to eliminate such common factors that affect the estimation result; including use of the cross-sectional means of the included explanatory variables as additional regressors in the model and use of all of the variables as deviations from their respective cross-sectional means in each period. The present study utilized the second procedure to eliminate common factors. To check whether the common factors that affect the panel simultaneously and causes misspecification are eliminated with demeaning or not, the present study conducted the cross-sectional dependence tests for the residuals obtained from the model estimated.

To this end, the most commonly used cross-sectional dependence test, LM test is utilized. Basically, the LM test proposed by Breusch and Pagan mainly designed for a long panel. Since the present study is a long panel study, LM is appropriate to test cross-sectional dependence between error terms of the cross-section. Table 5.8 below reports the results of these tests.

Table 5.8 Cross-sectional dependence test of residual resulting from PMG estimator

Cross-sectional dependence test

Series: residual from PMG estimator

Null-hypothesis: No cross-sectional dependence (correlation)

Test	Statistics	Df	P-value
Breusch-Pagan LM	101.9681	91	0.2029

Source: Own Estimation using Eviews 9.0

As can be observed, the P-value of the test statistic of Breusch-Pagan LM is statistically insignificant. Accordingly, the present study accepts the null-hypothesis of no cross-sectional dependence (correlation) between the residuals across cross-section under consideration. This proves that the estimated result does not show misspecification, resulting from cross-sectional dependence (or spatial correlation) of the residuals due to unobserved common factors. Therefore, one can say demeaning of the data eliminates the problem of the cross-sectional dependence among the residuals of the cross-section under consideration.

5.8.3 Other Diagnostics

In the literature, none of the panel-ARDL study conducted model diagnostic tests, except Pesaran et.al (1997; 1999) and Anne K, F (2013). These studies conducted diagnostics such as autocorrelation, heteroscedasticity, normality and functional form of the model by country. According to them, even though the study under analysis is panel study the model diagnostic tests are conducted by country since the time period for each cross-section is fairly long and the model is also established in the long time series of cross-sections. Given this, the model misspecification tests are made by cross-section to generalize for a panel. Accordingly, following Pesaran et.al (1997; 1999) and Anne K, F (2013), the present study made some model diagnostic tests by country in order to check the reliability and verifiability of the estimated long-run and short-run models. These tests include serial correlation (Brush and Godfray LM test), functional form (Ramsey's RESET test), normality (Jarque-Bera test), heteroscedasticity (Breusch-Pagan-Godfrey test). These tests can be compared among the cross-section and also used to generalize for the panel as a whole. The group-specific tests can be carried out after estimating the time series version of the above-selected panel-ARDL (1, 1, 1, 1, 1) model or ARDL (1, 1, 1, 1, 1) model for each country. Table 5.9 reports the results of four diagnostic tests which includes test of autocorrelation or serial correlation of the error term (Brush and Godfray LM test), test of functional form (Ramsey's RESET test), test of normality the error (Jarque-Bera test) and heteroscedasticity (Breusch-Pagan-Godfrey test) regarding the selected model by country (see in APPENDIX F in the appendices part of the paper). The null-hypothesis of these tests suggests that the model under investigation has no problem of autocorrelation, heteroscedasticity, functional form and normality. Given this, the guideline of the decision of the test is given as:

- ✓ Accept the null hypothesis of all the tests if the probability value of the computed F-statistics is greater than the 0.05 level of significance. This infers the model under estimation is fine or there is no problem of autocorrelation, heteroscedasticity, functional form and normality of the error.
- ✓ Accept the alternative hypothesis of all the tests if the probability value of the computed F-statistics is less than the 0.05 level of significance. This indicates that the model under estimation encounters a problem of the autocorrelation, heteroscedasticity, functional form and normality.

The results reported in Table 5.9 in APPENDIX F show there is no evidence of autocorrelation (serial correlation of the errors) in the model under estimation for all countries under investigation except for Burundi and Malawi (see first column in Table 5.9), no evidence of heteroscedasticity of the error term in the model estimated in all countries under analysis except Mauritius (see second column), no functional form misspecification in the case of all countries under study, except Comoros and Mauritius (see third column) and the error term is normally distributed in all countries except Madagascar, Mozambique, Seychelles, and Tanzania (see the fourth column). This shows, serial correlation is detected in 2 out of 14 countries, heteroscedasticity is detected in 1 out of 14 countries, functional misspecification is detected in two out of 14 countries and lastly, non-normality of the error-term is detected in 4 out of 14 countries. Therefore, the overall results of the diagnostics check are reassuring.

5.9 Interpretation and discussion of the PMG result

Recall the Table 5.5b, which reports the long-run and short-run slope coefficients of the selected panel-ARDL (1, 1, 1, 1, 1) model estimation via PMG estimator.

Table 5.5b Pooled Mean Group (PMG) estimation result

Dependent variable: D(LCO_2)
Method: Panel-ARDL
Model selection criteria: SBIC
Selected model: Panel-ARDL (1, 1, 1, 1, 1)
Estimator: Pooled Mean Group (PMG)

Variable	Coefficient	Standard error	t-statistics	P-values
		Long-run coefficients		
LTPEC	.9209388	.0868187	10.61	0.000***
LRGDPPC	.3548048	.1207925	2.94	0.003***
LPD	.2377611	.1260457	1.89	0.059*
UR	.1137519	.0255648	4.45	0.000***
		Short-run coefficients		
D(LTPEC)	.2100188	.0777958	2.70	0.007***
D(LRGDPPC)	.2247178	.1003338	2.24	0.025**
D(LPD)	.1658011	2.459899	0.07	0.946
D(UR)	-.0285118	.0172671	-1.65	0.099*
ECT_{-1}	-.2588951	.0630549	-4.11	0.000***
C	.0190305	.0670121	0.28	0.776
Log Likelihood = 468.8953				

Note: ***, ** and * indicate the rejection of a null hypothesis of statistical insignificance of the coefficients at 1%, 5% and 10% level of significance.
Source: Own Estimation using Eviews 9.0 and STATA 13.0

The estimated short and long-run coefficients of the PMG estimator can be interpreted as elasticities. The long-run results of the PMG estimation of the selected panel-ARDL(1, 1, 1, 1, 1) model in table 5.5b above indicates the explanatory variables total primary energy consumption, real gross domestic product per capita, population density and urbanization are positively and statistically significantly related to carbon dioxide emissions. The details of the result are discussed as follows;

Energy consumption: - In the long-run, total primary energy consumption has a significant positive impact on the log of carbon dioxide emissions in the selected fourteen East African countries(see table 5.5b above). The long-run elasticity of carbon dioxide emissions with respect to total primary energy consumption is 0.9. This implies, in the long-run, a 1 % change in the total primary energy consumption leads to a 0.9 % change in carbon dioxide emissions in a set of countries under study, keeping other things constant. In other words, in the long-run, for 1 % increase in the consumption of the total primary energy consumption, carbon dioxide emissions will increase by almost 1 % and vice versa in countries under study, citrus paribus. This argument is in line or consistent with the other past studies by Shemelis K (2017) who found a positive and significant impact of energy consumption on anthropogenic emissions of carbon dioxide when he investigated the link between energy use and carbon dioxide emissions in Ethiopia. Similarly, other single country studies by Rahmen and Kashem (2017) and Oh and Bhuyan (2018) for Bangladesh, Tang and Tan (2015) for Vietnam, Halicioglu (2009) for Turkey, Hassan and Nosheen (2018) and Mahmood and Chaudhary (2012) for Pakistan found energy consumption as a major determinant of anthropogenic emissions of carbon dioxide in the long-run. Further, the result of the study is also in accordance with the result of other past multi-country or panel studies by Asongu et al (2015) and Poku (2016) who found significant and positive long-run relationship between energy consumption and carbon dioxide emissions for the case of 24 African countries and sub-Saharan African countries, respectively. Other previous multi-country studies by Zaraya et al (2015) and Pao and Tsai (2015) for BRICS countries, Saboori and Sulaiman (2013) and Hilaire and Fotio (2015) provide the similar result which indicates energy consumption to significantly and positively affect carbon dioxide emissions.

The present study finding is interesting and also has important implications. Energy consumption highly contributes to the level of anthropogenic emissions of carbon dioxide in the countries under study. According to UNECA (2014), biomass energy consumption in East African countries accounts for about 80 % of the total energy mix. This means the highest share of energy consumption from the total energy mix of the countries under investigation comes from wood and wood-derived fuels and biomass waste consumption which are categorized as primary energy and environmentally unfriendly. Therefore, the consumption and its combustion results in a higher level of anthropogenic emissions of carbon dioxide in the countries under study.

In fact, biomass energy is the major energy type which is largely used and also contributes to the carbon dioxide emissions in the countries. On the other extreme, the increase in the demand for biomass energy will affect the stock of forests generally and trees particularly. In other words, the increase in biomass energy causes deforestation of trees and also the degradation of forests. It is well known that trees and forests provide environmental service as a form of carbon sink. From this, once the trees and forests are cleared for energy purpose the natural service of trees and forests as a carbon sink reduced and results in high carbon concentration in the atmosphere.

Economic growth:-In the long-run, economic growth or real gross domestic product per capita coefficient is found to be positive and statistically significant at 1% level (see Table 5.5b above). This suggests there is a positive relationship between anthropogenic emissions of carbon dioxide and the growth in output in the set of selected fourteen East African countries. This suggests that the increase in the level of economic growth or output will result in emissions of more carbon dioxide or higher economic growth will accelerate the level of carbon dioxide emissions. The long-run elasticity of carbon dioxide emissions with respect to economic growth or real gross domestic product per capita is 0.35. This indicates when the level of real gross domestic product per capita change by 1 %, the level of carbon dioxide emissions change by 0.35 % in the countries under analysis, other things remain constant. From this, the increase in the level of economic growth has a positive impact on carbon dioxide emissions in the selected fourteen Eastern African economies over the period under consideration. This result is in line with the other past studies by Shemelis K (2017) who found economic growth in Ethiopia increased anthropogenic emissions of carbon dioxide in the long-run. Furthermore, the present study result is in accordance with the result of other previous single and multi-country studies by Asongu et al (2015) for 24 African countries, Tang and Tan (2011) for Vietnam, Halicioglu (2009) for Turkey, Pao and Tsai (2015) and Zaraya et al for BRIC countries who found growth in output significantly affect anthropogenic emissions of carbon dioxide.

The result of the study is interesting because it has important implications. The increase in the real gross domestic product per capita or output means that there is high production in the sectors of the economy such as service, agriculture, and the industry as well as other informal sectors. Such production in the economy requires higher usage of inputs; the most prominent input is energy basically in the factories and industries. In other words, the increase in economic activities in the economy demands more factors of production which result in the consumption of energy to be quite high. In the same token, the expansion of industries and factories in the set of countries in the sample demands more inputs and the production process or the utilization of the inputs might also result in the pollutant emission into the atmosphere.

Backing to the agricultural sector where the highest share of gross domestic product/output/ for the countries under analysis to be generated, the increase in its output might result in more emissions of carbon dioxide. In fact, the agricultural output can be increased either via an increase in the area of land to be cultivated or the improvement in productivity in the sector. In most of the countries under analysis, the production process in the agricultural sector is traditional or not mechanized and its productivity is low. The increasing contribution of the agricultural sector to the economic growth in the countries under analysis might not be because of improvement in productivity but basically by increasing the area of land to be cultivated. This could result in more emissions of carbon dioxide by putting pressure on environmental resources.

To add, the increase in the output in the agricultural sector means the economic activity of the rural resident is increasing and then in order to further increase their output, the rural residents also demand more land area to cultivate and produce and such demand might result in unsustainable use of resources both economic and environmental which result in more emission of pollutant in to the atmosphere. In the agricultural sector, overgrazing and its related activities also have a significant impact on pollutant emissions.

Regarding the service sector, the contribution of the services sector to the growth of the economy increasing and among them, transportation is the most polluting sector in the countries under analysis. It is well known that transportation is basically based on fuel consuming cars and buses as well as airplanes. Therefore, the contribution of the transportation sector to the countries aggregate output is increasing but it also has an effect on the environment or increases the level of emissions through emitting more pollutant emissions into the atmosphere.

Generally, economic growth means the increase in economic activities in all sectors of the economy. Such increase in economic activities results in higher usage of fuels most notably in the factories and industries in the industry sector and transportation in the services sector and the increase in the area of land to be cultivated and grazed in the agricultural sector. These and other activities or production process carried out and the inputs used in the sectors might leads to emissions of more pollutants most notably carbon dioxide.

Population density: - In the long run, a coefficient of population density is found to be statistically significant at 10 % level (see table 5.5b above). Expectedly, it's coefficient exhibit positive sign and this suggests there is a positive relationship between the level carbon dioxide emissions and population density in the region over the period under analysis. The long-run coefficient or elasticity of population density is 0.24. This result is consistent with that of Semelis K(2017) for Ethiopia who found that population as a key determinant of anthropogenic emissions of carbon dioxide in the long-run, Mohmood and Chaudhary (2012) and Hassan and Nosheern (2018) for Pakistan who found that population density to positively and significantly affect carbon dioxide emissions in the long-run. And, the study by Oh and Bhuyan (2011) for Bangladesh found a significant and positive impact of population density on carbon dioxide emissions in the long-run. Furthermore, the result also corroborates the result of other multi-country studies by Hilaire and Fotio (2015) for Congo basin countries who found population density has a positive relationship with carbon dioxide emissions significantly and; Poku (2016) for Sub-Saharan African countries who found growth in population have significant and positive impact on carbon dioxide emissions of the region in the long-run.

Therefore, the result of the study has important implications. When the number of people per square kilometer or population density increases, it results in an increasing number of people with the lowest area of land to be cultivated and also an area for building. Then the demand for additional land for cultivation as well as for residential purpose increase. Such demand puts greater pressure on the natural resources of the area in the form of clearing forests and trees for the area of cultivation as well as building. But it is well known that these forest and trees provide services naturally as a carbon sink and once these forests and trees are cleared, the level of carbon in the atmosphere increases because of the carbon stored in trees and forests released into the atmosphere once they are cleared. In other words, the relative increase in population to the total area or population density leads to a greater utilization or usage of both economic and environmental resources directly and indirectly. Such exploitation of resources results in emissions of pollutions such as carbon and others.

Further, an increase in population density also affects the atmospheric concentration of carbon dioxide via energy consumption where a large population could result in increased demand for energy for power which leads to an increase in CO_2 emissions. Furthermore, an increase in population density has also been found to contribute to CO_2 emissions through its effect on production and consumption activities. Therefore, the increase in population density highly contributes to environmental degradation through over-exploitation of natural resources in the area.

Urbanization: - In the long-run, the coefficient of urbanization is found to be positive and statistically significant at 1 % level. This suggests that there is a positive relationship between anthropogenic emissions of carbon dioxide and the level of urbanization in a set of selected Eastern African economies over the period under analysis. The long-run elasticity of carbon dioxide emissions with respect to urbanization is 0.11. That is to say, keeping all other things fixed, a 1 % change in urbanization results in a 0.11 % change in the level of carbon dioxide emissions in the countries under investigation. The result is also in line with the other previous study by Poku (2016) for sub-Saharan African countries who found urbanization significantly and positively influences the anthropogenic emissions of carbon dioxide in the long run. But the result contradicts the result of a study by Semelis (2017) for Ethiopia who urbanization is insignificant in influencing carbon dioxide emissions in the country in the long run.

The finding of the study has an important implication. Basically, urbanization in a set of countries under investigation is characterized by a dramatic increase in land coverage of residential areas. This can be described as; the expansion of urbanization means an increase in the number of urban dwellers and urban activities. The increase in the number of urban dwellers results to an increase in the demand for residential building, the effect of which is an increase in demand for the land area for building, the result of which is clearing of forests in general and particularly trees and grasslands conversion into urban areas. Thus, carbon stored in the trees and other plants can be released due to its clearance of plants and results in increasing the concentration of carbon dioxide emissions in the atmosphere.

In addition to this, in a set of countries under study, land use control is totally absent in some small towns during urbanization and also weakly manifested in different other cities and towns. This will leads to an unplanned urban settlement that spread into pieces of farmlands, the effect of which is more degradation of forests and trees as well as the conversion of grasslands into residential areas, thereby leading to the high concentration of carbon in the atmosphere. Again, as the urban dwellers increase, the demand for urban residential houses/building has to increase which increase the demand for houses/building materials such as cement and lime. The resulting increase in the demand for cement and lime has increased its production, the effect of which is more emissions of carbon dioxide into the atmosphere.

Furthermore, in order to receive good urban utilities and social services such as electricity, clean water, and housing and also good employment opportunity a number of rural dwellers move to urban centers, the effect of which is the increase in heavy transportation, leading to high energy consumption in the form of fuel, and thereby increase emissions of pollutant. To add on transportation, in many large cities like Addis Ababa and other cities in the countries under investigation there is heavy traffic congestion, which increases the usage of energy consumption like fuel, thereby leads to an increase in carbon dioxide emissions into the atmosphere.

It is well known that pooled mean group (PMG) estimator provides consistent estimates of the mean of short-run coefficients for the panel or the whole sample by taking the simple average of the country-specific short-run coefficients. Given this, the short-run dynamic slope coefficients of the panel can be discussed in terms of average elasticities for the panel. While the country-specific short-run dynamic slope coefficients can be discussed as the deviation from the average elasticities of the panel.

Therefore, the short-run panel-ARDL (1, 1, 1, 1, 1) estimate of PMG estimator above indicates that the result for total primary energy consumption is in accordance with a long-run case which exhibits a positive relationship with carbon dioxide emissions in the selected countries under the study period. The short-run elasticity of carbon dioxide emissions with respect to total primary energy consumption is 0.21. Technically, on average, a 1 % change in the use of total primary energy consumption leads to 0.21 % change in carbon dioxide emissions in the region over the study period, keeping other things constant. This result also corroborates the results of the past studies by Shemelis K (2017) for Ethiopia, Asongu et al (2015) for 24 African countries, Rahman and Kasheem (2017) for Bangladesh and Saboori and Sulaiman (2013) for Association of Southeast Asian nations, the result of which indicates the increase in energy consumption has a worsening impact on the environment in the short-run via increasing the level of anthropogenic emissions of carbon dioxide.

Similarly, in the short-run, real gross domestic product per capita has also significant and positive observable impact on carbon dioxide emissions in the region. The short-run elasticity of carbon dioxide emissions with respect to real gross domestic product per capita is 0.22. That is to say, on average, a 1 % change in the level of real gross domestic product causes, a 0.22 % change in the level of carbon dioxide emissions, keeping other thongs constant. This implies that there is a positive relationship between the level of anthropogenic emissions of carbon dioxide and growth in output in the short-run too. The result is consistent with the previous study by Asongu et al (2015) for 24 African countries, Hassen and Nosheem (2018) for Pakistan, Tang and Tan (2015) for Vietnam and Halicigolu F (2009) for turkey.

However, unlike that of the long-run analysis, population density is insignificant and on average, it does not have any impact on carbon dioxide emissions in the region over the analyzed period. This result is in accordance with the result of the previous studies by Oh and Bhuyan (2018) for Bangladesh who found the insignificant short-run impact of population density on carbon dioxide emissions.

The finding has also important implications. It is well known that the relative increase in the number of population to the total area of land will cause pressure on natural resources in the form of searching addition land for agriculture as well as residential purpose. This, in turn, causes high deforestation and degradation of trees or generally forests. Since deforestation is not the short-term phenomenon, the impact of such action cannot be observed immediately but through time it becomes apparent and results in more carbon dioxide emission concentration in the atmosphere. Therefore, the impact of population density is insignificant in influencing the level of anthropogenic emissions of carbon dioxide in the countries under analysis in the short-run.

In the short-run, the coefficient of urbanization significant yet it is in a statistical sense but unlike the long-run coefficient, it is negative. The short-run elasticity of carbon dioxide emissions with respect to urbanization is 0.028, a sign of which is negative. Technically, on average, a 1 % changes in urbanization results in a 0.028 % change in anthropogenic emissions of carbon dioxide in a set of countries under study, assuming other things fixed. This suggests that on average there is a negative relationship between the level of anthropogenic emissions of carbon dioxide and urbanization in the short-run.

The finding also has important implications. As it was discussed in the long-run analysis case, an increase in urbanization means an increase in urban resident and activities. The growth in urban dwellers could occur through the growth of permanently residing urban population or natural population growth within the cities, rural-urban as well as urban-urban migration due to an imbalance between the availability of resources as well as job opportunities and a number of population. It is well known that the present day emission in the region is predominantly from rural activities, such as agriculture, livestock, deforestation and degradation of forests in general and tress in particular for the purpose of home cooking and expansion of agricultural lands.

Therefore, once the rural dwellers move from rural to urban areas, the pressure on those natural resources in the rural part of the country could decrease in the form of a decrease in the consumption of biomass, reduce in the expansion for agricultural land an also reduction in the impact of overgrazing. This will contribute to the reduction of pollutants emission most notably carbon dioxide because combustion of biomass for cooking and use of kerosene for home lighting in rural could be replaced by hydro-electricity which is environmentally friendly. But the migrated people in the urban center also have a significant influence on the environment through the generation of waste and an increase in energy consumption.

At the same time migrated people clear the trees and other plants for residential purpose, but the impact of such clearance of trees for urban areas doesn't be observed immediately since deforestation is not a short-run phenomenon rather it a long-term phenomenon and its impact also observed through time. Thus, a negative impact of urbanization in the short-run is might be because of a positive contribution of rural-urban migration on environmental quality via reduction of stress on the natural resources in the rural part of the region out weights the negative environmental impact of migrated people in the urban center of the region.

The error-correction term coefficient is found to be highly statistically significant and also exhibits the correct sign. This coefficient indicates the speed of adjustment of any disequilibrium towards long-run equilibrium or the equilibrium error-correction coefficient. The estimated error-correction term coefficient is 0.25, a sign of which is negative. This suggests that, on average, approximately 25 % of the previous year shock has been dying out currently. Similarly, on average, the previous year shock converges back to the long-run equilibrium in each year by about 25 %. As clearly discussed earlier, such a strongly significant error-correction term coefficient confirm the existence of the long-run relationship between the model variables. Therefore, from this result, one can infer that the variables under investigation (carbon dioxide emissions, real gross domestic product per capita, total primary energy consumption, population density, and urbanization) have a long-run co-integrating relationship.

To conclude, as it clearly discussed above, the panel elasticity of carbon dioxide emissions with respect to total primary energy consumption and real gross domestic product per capita is positive both in the short and long-run. The long-run elasticities of carbon dioxide emissions with reference to both total primary energy consumption and real gross domestic product per capita are found to be greater than short-run elasticities. This implies, over time, high energy consumption and economic growth in a set of countries under investigation lead to more anthropogenic emissions of carbon dioxide. Comparing the long-run coefficient or elasticities of total primary energy consumption and real gross domestic product per capita with respect to carbon emission, the long-run elasticity of total primary energy consumption is found to be greater than the long-run elasticity of real gross domestic product per capita in a set of the countries under analysis. Thus, one can conclude that carbon dioxide emission is more responsive to the increase in energy consumption than economic growth in the long-run. Therefore, energy consumption is more responsible factor for the increase in carbon dioxide emissions than economic growth in the long-run.

Backing to short-run coefficients or elasticities of total primary energy consumption and real gross domestic product per capita with reference to carbon dioxide emissions in countries under study, the short-run elasticity of total primary energy consumption is found to be lower than the short-run elasticity of real gross domestic product per capita. This implies carbon dioxide emission is more responsive to economic growth than energy consumption in the short-run. Thus, economic growth is more responsible factor for the increases in the level of carbon dioxide emission in the short-run compared to energy consumption. Regarding population density, the elasticity of carbon dioxide emissions with respect to population density is significant in the long-run but not in the short-run. The sign of the elasticities of carbon dioxide emissions with respect to urbanization is found to be different, which is positive in the long-run and negative in the short-run, implying urbanization affects anthropogenic emissions of carbon dioxide positively and negatively in the long-run and short-run, respectively.

5.9.1 The short-run individual country pooled mean group (PMG) estimation result

According to Pesaran et, al (1997; 1999), one advantage of the pooled mean group (PMG) estimator over the dynamic fixed effects (DFE) is that it provides individual country-specific short-run dynamic slope coefficients. These individual country-specific short-run coefficients allow the comparative analysis between the mean of the short-run coefficients of the panel and individual country-specific short-run coefficients. This is possible because PMG estimator provides consistent estimates of the mean of short-run coefficients by taking the simple average of the country-specific coefficients. The comparison between the average short-run coefficients of the panel and country-specific short-run coefficients is based on the magnitude of the coefficients.

For instance, if the individual country short-run coefficient of total primary energy consumption is larger than its average coefficient of the panel, one can say that the country is emitting more than the countries average from the energy sector and vice versa. From Table 5.10 in APPENDIX G, the short-run coefficient of total primary energy consumption in Burundi is about 0.11 %, while the average short-run coefficient of total primary energy consumption is about 0.21 %. Therefore, Burundi emits less carbon dioxide from energy use compared to the average.

Given this, the details on the individual country specific short-run slope coefficients are discussed below.

Compared to the average short-run coefficient of total primary energy consumption of the panel (0.21), the largest short-run coefficient of total primary energy consumption is observed in Comoros, Ethiopia, Kenya, Seychelles, Zambia and Zimbabwe, the result of which reveals energy consumption in these economies affect carbon emissions by more the panel average. The short-run elasticity of carbon dioxide emission with respect to total primary energy consumption in the above-listed countries is 0.24, 0.26, 0.4, 0.39, 0.98 and 0.34, respectively. Technically, a 1 % change in total primary energy consumption in Comoros, Ethiopia, Kenya, Seychelles, Zambia, and Zimbabwe causes a 0.24 %, 0.26 %, 0.4 %, 0.39 %, 0.98 % and 0.34 % change in carbon dioxide emission, respectively, assuming other thing remains constant. Therefore, one can conclude that a carbon dioxide emission in these economies is more elastic to a change in total primary energy consumption compared to its average elasticity. In other words, total primary energy consumption contributes more to the atmospheric concentration of carbon in the above-listed countries compared to its average.

Further, among the sample of fourteen countries of the region, these economies such as Comoros, Ethiopia, Kenya, Seychelles, Zambia and Zimbabwe are found to be more emitting countries from energy sector and also within these countries Zambia is the most emitting country from the energy sector because the elasticity of carbon dioxide emission is more elastic to a change in total primary energy consumption. However, Burundi, Malawi, Mozambique, Rwanda, and Uganda are found to be less emitting countries from energy consumption compared to the average and within these countries, Malawi is found to be less emitting country followed by Mozambique. This is observed from the short-run coefficients of carbon dioxide emissions with respect to the total primary energy consumption of the countries under study (seen from table 5.10 in APPENDIX F). Furthermore, the country-specific short-run coefficient of total primary energy consumption is statistically insignificant in the case of Madagascar and Tanzania while negatively statistically significant in the case of Mauritius. This is might be the energy mix in Mauritius accounts more renewables or environmentally friendly compared to other fossil fuel energy.

Backing to the individual country regression result of real gross domestic product per capita in column two of table 5.10 in APPENDIX G, its coefficient is found to be statistically significant only in five countries such as Ethiopia, Madagascar, Malawi, Mozambique, and Zimbabwe. Among statistically significant coefficients, four of them namely the coefficient of real gross domestic product per capita in Ethiopia, Malawi, and Mozambique reveals the positive relationship between carbon emissions and growth in output whereas its coefficient in Zimbabwe indicates a negative relationship between carbon emissions and output growth. Further, the largest coefficient is observed in Madagascar followed by Ethiopia, Malawi, and Mozambique, the result of which infers the countries in that order are the most emitting countries from growth in output in the economy. This implies, the economic activities in these countries are not that much environmentally friendly and energy efficient. Statistically, the short-run elasticity of carbon dioxide emission with reference to real gross domestic product per capita in Ethiopia, Madagascar, Malawi, Mozambique, and Zimbabwe are 0.36, 1.12, 0.05, 0.046 and -0.22. Figuratively, a 1 % change in real gross domestic product per capita leads to a 0.36 %, 1.11 %, 0.05 % and 0.046 % change (increase) in carbon dioxide emissions, respectively in Ethiopia, Madagascar, Malawi, Mozambique and 0.22 % change (decrease) in carbon dioxide emissions in Zimbabwe, keeping all other things constant.

In Table 5.5b above, the short-run average coefficient of real gross domestic product per capita is 0.22. From this, the short-run coefficients of real gross domestic product per capita in Ethiopia and Madagascar are found to be larger than its average. This implies economic growth in Ethiopia and Madagascar contributes more to the increase in carbon emissions compared to its average. From this, taking economic growth into consideration, Madagascar is found to be the most emitting country in a set of fourteen Eastern African countries under study followed by Ethiopia since carbon dioxide emission is more elastic to a change in real gross domestic product to other countries in the sample.

Backing to Malawi and Mozambique, their real gross domestic product per capita coefficients fall below the average. Therefore, the contribution of their real gross domestic product per capita on their carbon dioxide emissions is lower than it's average. This implies that the two countries namely Malawi and Mozambique are emitting less from their real gross domestic product per capita. Further, real gross domestic product per capita in Zimbabwe is also found to statistically significant in the short-run, but its sign is negative. The negative impact of the real gross domestic product per capita on carbon dioxide emission in Zimbabwe is might be linked with the economic performances of the country which was observed in the trend analysis of the data.

Unlike the panel short-run regression result, the individual country specific regression result shows that the coefficient of the population density is statistically significant only in the case of Rwanda and Uganda (see table 5.10 in APPENDIX G). The results indicate other things remain constant; a 1 % change (increase) population density causes a 0.78 % change (increase) in carbon dioxide emission in Rwanda and 0.44 % change (decrease) in carbon emissions in Uganda.

Regarding urbanization, the individual country regression result reveals its coefficients are statistically significant in all of the countries in the study and exhibits negative sign in all country case, except Rwanda, Seychelles, and Uganda. This suggests that urbanization reduces carbon dioxide emissions in all of the countries under study except Rwanda, Seychelles, and Uganda in the short-run. Urbanization in Rwanda, Seychelles and Uganda have an increasing impact on carbon dioxide emissions in short-run too because as can be seen from the data description analysis of the paper in chapter three, urbanization rate was found to be high in Rwanda and Uganda and Seychelles in that order.

Further, as it can be seen from column five of table 5.10 in APPENDIX G, the error-correction term is found to be statistically insignificant only in Burundi. Basically, the error-correction term shows the speed at which any shock in the previous year has to be adjusted currently or how much time the adjustment process of the last year shock takes in order to come back to a long-run state of equilibrium.

From Table 5.10, the fastest convergence from disequilibrium to long-run state of equilibrium is observed in Mauritius followed by Zimbabwe, Madagascar, Tanzania, Malawi, and Kenya. In these economies, the speed at which the last year error/shock/ returns back to the long-run equilibrium is found more than the average. As it can be discussed in the panel short-run regression result, the coefficient of the speed of adjustment term was about 25%, which was lower than its short-run coefficient in Mauritius, Zimbabwe, Madagascar, Tanzania, Malawi, and Kenya. From this, one can understand that the adjustment process of the last year shocks to the long-run equilibrium take a few periods in these economies compared to the average. On the other extreme, the slowest convergence is observed in Rwanda followed by Mozambique, Ethiopia, Zambia, Uganda, Comoros, and Seychelles. From this, one can understand that the adjustment process needs more time in order to come back to the long-run state of equilibrium in these economies compared to the average.

5.10 Pairwise Granger causality test result

In order to identify the direction of causality between the dependent variable (carbon dioxide emission) and independent variables (energy consumption (total primary energy consumption), economic growth (real per capita GDP), population density and urbanization, a Granger causality test is employed. Table 5.11 reports the result of the Granger test.

Table 5.11: pairwise Granger causality test result

Null hypothesis	Lag one	
	F-statistics	P-values
LTPEC does not Granger cause LCO_2	12.6299	0.0004***
LCO_2 does not Granger cause LTPEC	18.3473	2.E-05***
LRGDPPC does not Granger cause LCO_2	19.1415	1.E-05***
LCO_2 does not Granger cause LRGDPPC	1.39986	0.2373
LPD does not Granger cause LCO_2	42.2978	2.E-10***
LCO_2 does not Granger cause LPD	0.03114	0.8600
UR does not Granger cause LCO_2	1.02592	0.3116
LCO_2 does not Granger cause UR	1.04745	0.3066
LRGDPPC does not Granger cause LTPEC	44.1526	8.E-11***
LTPEC does not Granger cause LRGDPPC	4.41519	0.0361**

Note: *** and ** indicates the significance of the coefficients at 1% and 5% level, respectively
Source: own computation using Eviews 9.0

The Granger test shows that there is bidirectional causality between energy consumption (total primary energy consumption) and carbon dioxide emission. This implies that energy consumption and carbon dioxide emission are mutually interdependent and an increase in energy consumption causes carbon dioxide emission and vice versa. This result is in line with both the long and short-run estimation result which claims energy consumption is the major factor behind increasing carbon dioxide emission in the analyzed countries.

Further, the Granger test reveals economic growth (real per capita GDP) and population density does granger causes carbon dioxide emission but the reverse doesn't hold, indicating unidirectional causality running from economic growth and population density to carbon dioxide emission. The unidirectional causality or relationship between economic growth, population density, and carbon dioxide emission suggests that economic growth and population density cause only carbon dioxide emission and carbon dioxide emission doesn't cause economic growth and population density to change. The result corroborates with the long-run estimation result, which claims both economic growth and population density are long-run drivers of the regions carbon dioxide emission, but it doesn't support the short-run result of population density, which claims the insignificant effect of population density on carbon dioxide emission. Furthermore, the Granger test shows urbanization doesn't Granger-cause carbon dioxide emission and also a carbon dioxide emission doesn't cause urbanization to change. This result is more or less in line with the short-run estimation result because in the short-run the impact of urbanization on carbon dioxide emissions doesn't have a significant impact in the economic sense. However, in the long-run, its effect on carbon dioxide emissions will rise even though its effect will still be low compared to other variables long-run coefficients.

Finally, the granger test between energy consumption and economic growth found that there is a feedback effect among them. This is observed from the result that claims bidirectional causality between total primary energy consumption and real per capita GDP, indicating both energy consumption and economic growth are mutually interdependent and hence jointly determined in the countries under study. In other words, both economic growth and energy consumption act as a complement to each other, and hence an increase in energy consumption results in an increase in economic growth and vice versa. Given this, it is important to consider the impact of possible negative effects on economic growth in establishing energy conservation policies in the region.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The present study examines how energy consumption, growth in output, population density and urbanization influenced CO_2 emissions in a set of fourteen Easter African countries over the period 1980-2016, except for Ethiopia (1981-2016), Tanzania (1988-2016), and Uganda (1982-2016). It also investigated the variables in the model that are responsible for increasing carbon emissions both in the short-run and long-run. In order to analyze the short-run and long-run effects of the regressors, the study utilized the panel-ARDL model since it provides the long-run and short-run estimates simultaneously. It also accommodates the variables with mixed order of integration but not beyond integrated of order one. The study tested the integration order and co-integration of the variables under consideration. The integration order of the variables under study was ascertained by utilizing three-panel unit root tests: Im, Pesaran and Shin (2003), Fisher-ADF and Fisher-PP. The Kao (1999) residual-based panel co-integration test, Wald-test and the statistical significance of the error-correction term were used to check the long-run relationship between the variables. The tests showed that the variables under study have mixed order of integration (carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita were integrated of order one whereas population density and urbanization were integrated of order zero and none of the variables were integrated of order two).

Further, the results from Kao (1999) residual-based panel co-integration test, Wald-test and the statistical significance of the error-correction term also show strong evidence of a long-run relationship between the variables. Schwarz-Bayesian Information Criteria (SBIC) was utilized in order to select the optimal lags for the model and the result suggested one or 1 lag for the variable under study and the model became panel-ARDL (1, 1, 1, 1, 1). The study further tested a number of standard model diagnostics to establish the efficiency of the model and the results were reassuring and confirmed the overall significance of the model.

Furthermore, the study used three panel-ARDL model estimators: the mean group (MG), the pooled mean group (PMG), and the dynamic fixed effects (DFE). To select among these estimators the study used the Hausman (1978) test. The results suggested that the pooled mean group (PMG) estimator dominate the other two estimators.

In the long-run pooled mean group (PMG) estimation, the study found has a positive relationship between carbon dioxide emissions and total primary energy consumption, real gross domestic product per capita, population density and urbanization. This suggested that energy consumption, economic growth, population, and urbanization are the long-run drivers of the CO_2 emissions. Form the short-run panel pooled mean group (PMG) estimation; total primary energy consumption and real gross domestic product per capita were positively affecting the level of carbon dioxide emissions.

This also suggested the two variables, energy consumption, and economic growth, drives the level of carbon emissions in the short-run too. Population density has an insignificant in the short-run while urbanization reduces the level of carbon dioxide emissions yet is in the statistical sense. In the short-run individual country-specific pooled mean group (PMG) estimation, energy use in Comoros, Ethiopia, Kenya, Seychelles, Zambia, and Zimbabwe increased the level of anthropogenic emissions of carbon dioxide by more than the panel average. This suggested that the countries in that order emit more carbon dioxide from their energy consumption. Regarding economic growth, Madagascar and Ethiopia in that order were found to be the most emitting countries from growth in their economic activities. Unlike the panel-short-run estimate, urbanization in Rwanda, Seychelles, and Uganda increased the level of carbon emissions in the short-run.

The Granger test found bidirectional causality between carbon dioxide emission and energy consumption as well as energy consumption and economic growth. Further, the Granger test reveals unidirectional causality running from population density and economic growth to carbon dioxide emission, but no causality between urbanization and carbon dioxide emission.

6.2 Recommendations

Although this study captures the impacts and degrees of impacts of energy consumption, economic growth, and other demographic variables such as population density and urbanization on anthropogenic emissions of carbon dioxide and not the underlying ways for these impact improvements, some general recommendations can be suggested in the light of this study results as follows:

- ✓ From the results, energy consumption is found to the key deriving factor behind increasing of carbon dioxide emission in the region in both the short and long-run. Such a positive impact of energy consumption might be due to the high share of unclean or environmentally unfriendly energy in the total energy consumption and low penetration of clean energy in the analyzed countries. But, the Granger test suggests that energy consumption is a complement to the region's economic growth. Therefore, energy conservation policy has an important negative effect on the region's economic growth performance. Given this, first, there is a need for East African countries to invest more in cleaner energy alternatives such as biofuels, biogas, wind, solar, and hydro. In this regard, almost all of the countries under investigation prefer and budget high public investment on modern renewable energy development and modernization of the traditional biomass sector and adjusting the energy mix. However, there are potential challenges facing the countries in the spread of renewable energy technologies and development of the modern renewable energy source such as high initial investment and development cost, awareness problem among the users, institutional and capacity difficulties, international and regional challenges regarding the development of the hydro and other resources. Second, there is a need for the national and local governments of the analyzed countries to coordinate, design and implement effective mechanism to tackle such challenges and to optimize the energy consumption structure. Third, there is a need for East African countries to raise awareness of different community groups or sections of the society for green and environmentally friendly renewable energy sources. In this regard, proper education and training, and positive incentive to community members for sensible and efficient use of energy will really be helpful. Finally, there is a need for East African countries to work more on research and investment in clean energy alternative because research and investment is the part and parcel of energy policies of the countries to combat CO_2 emissions in particular and environmental degradation in general. Therefore, technological improvement via research and development will help the countries to optimize the energy consumption structure.

- ✓ From the result, economic growth also found the key driver behind increasing the level of anthropogenic emissions of carbon dioxide in 14 selected East African countries in both the short and long-run. This is might be due to their economic growth is highly inefficient in energy use and also pollution dependent. Therefore, there is a need for East African countries to take a policy measures to achieve low-carbon economies via green investments in the field of clean technologies and thereby lowering the opportunities of further carbonization of the structure of the economies. In this regard, the general economic activity, energy consumption, industrial production, agricultural development, and other sectors and activities in the economies of the analyzed countries are better to be aligned with their green growth strategies.
- ✓ The result also confirmed that both population and urbanization are the key long-run deriving factors behind the increase of carbon dioxide emissions in 14 selected East African countries. Therefore, there is a need for policymakers in the analyzed countries to take in to account the dynamics of urbanization and population when designing policies regarding environmental protection. Also, the responsible body takes into consideration the impact of population and urbanization when negotiating international, regional and local agreements regarding the climate change which all of the countries under study facing today. Furthermore, there is a need for East African countries to control the rate of population growth via intervention programs. The possible intervention mechanisms are women empowerment, improving girl education, and creating awareness on negative effects of having a large family size not only on the natural environment but also on the socio-economic aspects of life such as education, health, and standard as well as the cost of living via education and training.

6.3 Limitation and future research direction

The study limited itself only with the relationship between energy consumption, economic growth, population density, urbanization and CO_2 emission in 14 selected East African countries which covers the annual data for all respective economic variables from the period 1980 up to 2016, except Ethiopia (1981-2016), Tanzania (1988-2016) and Uganda (1982-2016). During the overall investigation of this study, the main limitation was associated with data availability in some variables, particularly energy consumption and CO_2 emission. The period of the study goes only up to 2016, due to a lack of more recent data for the countries under analysis, especially data on energy consumption and CO_2 emission.

Given the importance of the area and inconclusiveness of previous studies, future researches better to be done particularly on the multivariate framework that investigating the energy consumption-economic growth-environmental interaction by adding other important variables simultaneously by taking recently available data.

References

Acaravci, A. & Ozturk, I. (2010). On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy, 35, 5412-5420

ADB (2018). East Africa economic outlook. African Development Bank Group report

ADB (2014). African Development Bank. a partner of choice for Eastern Africa we want, East African regional resource Centre (EARC), Nairobi, Kenya

ADB & OECD (2002). African Economic Outlook 2002. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB & OECD (2004). African Economic Outlook 2004. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB & OECD (2005). African Economic Outlook 2005. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB & OECD (2006). African Economic Outlook 2006. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB & OECD (2007). African Economic Outlook 2007. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB & OECD (2008). African Economic Outlook 2008. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB & OECD (2010). African Economic Outlook 2010. Africa Development Bank and the Organization for Economic Cooperation and Development

ADB, OECD & UNDP (2015). African Economic Outlook. Africa Development Bank, Organization for Economic Cooperation and Development and United Nations Development Program

ADB, OECD & UNDP (2017). African Economic Outlook. Africa Development Bank, Organization for Economic Cooperation and Development and United Nations Development Program

ADB, OECD, UNDP & UNECA (2011). African Economic Outlook. Africa Development Bank, Organization for Economic Cooperation and Development, United Nation Development Program and United Nations Economic Commission for Africa

Adom, P, K.(2016). Energy demand management in selected African countries. Swedish University of agricultural science, ISSN: 1652-6880

Adu, T, D. & Elisha, F, D.(2017). Economic growth and environmental pollution in West Africa: Testing the Environmental Kuznets Curve hypothesis. Kasetsart journal of social sciences, XXX, 1-8

Alam, Md, M, Md, Wahid, M. Abu, H., Md, N. & Ilhan, O. (2016). Relationships among carbon emissions, economic growth, energy consumption, and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India, and Indonesia. Ecological Indicators, 70, 466-479

Aliha, M, P. Sarmidi, T. Shaar, H, A. & Said, F, F.(2017). Using the ARDL approach to co-integration for investigating the relationship between payment technologies and money demand on a world scale. Regional science inquiry, IX(2), 29-37

Anne, K, F.(2013). An econometric analysis of Norwegian mainland exports. Copenhagen business school, Denmark

Apergis, N. & James, E, P.(2010). The emissions, energy consumption, and growth nexus: Evidence from the Commonwealth of independent states. Energy policy, 38, 650-655

Aqeel, A. & Butt, M, S.(2001). The relationship between energy consumption and economic growth in Pakistan. Asia Pacific Development Journal, 8(2), 101–110

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices, and economic growth: time series evidence from Asian developing countries. Energy Economics, 22, 615-625

Asongu, S. Ghassan, El, M. & Hassen, T.(2015). Testing the relationships between energy consumption, CO_2 emissions and economic growth in 24 African countries: a panel-ARDL approach, DOI 10.1007/s11356-015-5883-7

BP (2015). The energy challenges and climate change. BP sustainability report

BP (2018). BP statistical reviews of world energy. Retrieved http://www.bp.com/statisticalreview

Demetriades, P. & S. H. Law (2006). Finance, Institutions and Economic Growth. International Journal of Finance and Economics, 11(3), 245-260

EIA (2016). Energy Information Administration: International energy outlook in 2016.

Engle RF, Granger CWJ (1987). Co-integration and error correction: Representation estimation and testing. Econometrica 55:251-276

Endeg, T, W. (2015). Economic growth and environmental degradation in Ethiopia: An Environmental Kuznets curve analysis approach. Journal of economics and international finance, 7(4), 72-79

Endeg, T, W. Wendaferahu, M. & Muhadin, M, H. (2016). Energy consumption, carbon dioxide emissions, and economic growth in Ethiopia. Global Journal of management and business Research economic and commerce, 16, online ISSN: 2249-4588 and print ISSN: 0975-5853

Esso, J, L. & Yaya, K. (2016). Energy consumption, economic growth, and carbon emissions: Co-integration and causality evidence from selected African countries. Energy, 114, 492-497

Everett, T. Mallik, I. Gian, P, A. & Alex, R. (2010). Economic growth and the environment. Defra evidence and analysis series, paper 2

Fuzli, P. & Abbasi, E.(2018). Analysis of the validity of the Kuznets curve of energy intensity among D-8 countries: Panel ARDL Approach. International letters of social and humanistic science. ISSN: 2300-2697, 81, 1-12

GDAE (2017). The economics of global climate change. Global development and environmental institute, Tufts University

GCA (2018).”Global Carbon Atlas online statistics”, Global Carbon Atlas (2018).

Grossman, G, M. & Krueger A, B.(1991). Environmental impacts of A North American Free Trade Agreement. NBER Working Paper series.No.3914

Giles David. (2013). Econometrics Beat”: Dave Giles' Blog: ARDL Models - Part I and 2

Goldberger, A, S.(1991). A course in econometrics. Harvard University pers: Cambridge UK, ISBN: 978-0674/75440.

Gujarati, D, N, J. & Porter, D, C.(2009). Basic Econometrics, 5th edition. McGraw-hill/Irwin; New York, NY, USA

Haicioglu, F.(2009). An econometric study of carbon emissions, energy consumption, income and foreign trade in Turkey. Energy policy, 37, 1156-1164

Hamilton. C. & Turton, H. (2002). Determinants of emissions growth in OECD countries. Energy policy, 30, 63-71

Hassan, A, S. & Nosheern, M.(2018). The impact of air transportation on carbon dioxide, methane and nitrous oxide emissions in Pakistan": Evidence from ARDL modeling approach. International journal of innovation and economic development, 3(6), 7-32

Hausman, J, A. (1978). Specification tests in Econometrics. Econometrica, 46(6), 1251– 1271

Henley, N. Jason, F, S. & Ben, W.(1997). Environmental economics in theory and practice. MACMILLAN PRESS LTD, London

Hilaire, N. & Fotio, K, H.(2015). Effect of economic growth on carbon dioxide emissions in the "Congo Basin" countries. International journal of economics and finance, 7(1) ISSN: 1916-977X: E-ISSN: 1916-9728

Huang, B., M.J. Hwang, & C.W. Yang (2008). The causal relationship between energy consumption and GDP growth revisited: A dynamic panel data approach. Ecological Economics, 69, 41-54

IEA (2017). International energy agency, Global energy and CO_2 emissions status report

Im, K.S., Pesaran, M.H., Shin, Y. (2003). Testing for Unit Roots in Heterogeneous Panels. Journal of Econometrics, 115(1), 53–74

Jumbe, Charles. B.L.(2004). Co-integration and causality between electricity consumption and GDP: empirical evidence from Malawi. Energy Economics, 6, 61-68

Kao, C, D.(1999). Spurious regression and residual-based tests for co-integration in panel data. Journal of Econometrics, 90(1), 1–44

Kraft, J. & Kraft, A. (1978). On the relationship between energy and GNP. Journal of energy development, 3, 401–403

Kulionis, V.(2013). The relationship between renewable energy consumption, CO_2 emissions and economic growth in Denmark. School of economics and management, Lund University

Kutu, A.A and Ngalawa, H (2016). Dynamics of industrial production in BRICS countries. International journal of economics and finance studies, 8 (1) ISSN: 1309-8055

Maddala, G. S. & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and statistics, 61(S1), 631-652

Marques, C., Fuinhas, A., Manso, J (2010). Motivations driving RE in European countries: A panel data approach. Energy Policy, 38, 6877-6885

Narayan, P. K (2005). The saving and investment nexus for China: evidence from co-integration tests. Applied Economics, vol. 37(17), 1979-1990

Mahmood, H, and Chaudhary, A. R (2012). FDI, population density and carbon dioxide emissions: A case study of Pakistan. Iranica Journal of energy and environment, 3 (4), 356-360

Oh, Y.K and Bhuyan, I.M (2018). Trade openness and carbon dioxide emissions: Evidence from Bangladesh. Asian Journal of atmospheric environment, 12(1), 30-36

Ohlan. R (2015). The impacts of population density, energy consumption, economic growth, and trade openness on CO_2 emissions in India. Nat Hazards, 79, 1409-1428. DOI 10.1007/s11069-015-1898-0

Omari, A (2013). CO_2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. MPRA, Paper No. 82501

Özokcu, S and Özdemir, Ö (2017). Economic growth, energy, and environmental Kuznets curve. Renewable and sustainable energy reviews, 72, 639-647

Ozturk, I (2010). A literature survey on energy –growth nexus. Energy Economics, 38, 340-349

Ozturk. I and Acaravci. A (2010). CO_2 emissions, energy consumption and economic growth in Turkey. Renewable and sustainable energy reviews, 14, 3220-3225

Panayotou, T (2003). Economic Growth and the Environment, Economic Survey of Europe No.2.

Pao, T.H and Tsai, M.C(2011). Multivariate Granger causality between carbon dioxide emissions, energy consumption, foreign direct investment, and economic growth: Evidence from panel BRICS countries. Energy, 36, 685-693

Pesaran, M. H (1997). The role of economic theory in modeling the long-run. The Economic Journal, 107(440), 178-191

Pesaran, M. H & Shin, Y. (1999). An Autoregressive Distributed Lag Modeling Approach to Cointegration" in Econometrics and Economic Theory in the 20th Century. The Ragnar Frisch Centennial Symposium Cambridge University Press, chapter. 4, 371-413

Pesaran, M.H., Shin, Y., and Smith, R.P (1997). Structural Analysis of Vector Error Correction Models with Exogenous I (1) Variables. Dept. of the Applied Economics University of Cambridge.

Pesaran, M.H., Shin, Y. and Smith, R. P (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. Journal of the American Statistical Association, 94(446), 621-634. DOI: 10.1080/01621459.1999.10474156

Pesaran, M.H and Smith, R.P (1995). Estimating long-run relationships from the dynamic heterogeneous panel. Journal of Econometrics, 68(1), 79-113

Poku, A. F (2016). Carbon dioxide emissions, urbanization, and population: Empirical evidence in Sub-Saharan Africa. Energy economics letters, 3 (1), 1-16

Rahman, M.M and Kashem, A.M (2017). Carbon emissions, energy consumption and industrial growth in Bangladesh. Empirical evidence from ARDL co-integration and Granger causality analysis. Energy Economics, 110, 600-688

Raheem, D.I and Yusuf, A.H (2015). Energy Consumption-Economic Growth Nexus: Evidence from Linear and Nonlinear Models in Selected African Countries. International journal of energy economics and policy, 5(2), 558-564

Saboori, B and Sulaiman, J (2013). Carbon dioxide emissions, energy consumption and economic growth in the Association of Southeast Asian Nations (ASEAN) countries. Energy, 55, 813-822

Saidi. K and Sami. H (2014). Energy consumption and economic growth nexus: empirical evidence from Tunisia. American journal of energy research, 2(8), 81-89

Saiful, I. M, Tarique, K.M and Sohng, G. K (2014). Carbon dioxide emissions and agricultural productivity in the Southeast Asian region: pooled mean group estimation. A scientific journal of conscious, science vision, 20(1), 93-99

Samargandi, N, Tan, F and Sugata, G (2013). Is the relationship between financial development and economic growth monotonic for middle-income countries?. Economics and finance working paper series; working paper No 13-21

Shemelis. K (2017). Modeling energy consumption, CO_2 emissions and economic growth nexus in Ethiopia: evidence from ARDL approach to co-integration and causality analysis. MRPA paper No.83000

Stern, D (2003). The environmental Kuznets Curve. International society for ecological economics

Tang, F.C and Tan, W.B (2015). The impact of energy consumption, income and foreign direct investment on carbon dioxide emissions in Vietnam. Energy, 79, 447-454

UNECA (2014). United Nations Economic Commission for Africa report. Energy access and security in Eastern Africa

UNECA (2018). United Nations Economic Commission for Africa report. Macroeconomic and social development in Eastern Africa

UNFCCC (2006). United Nation United Nations Framework Convention on Climate Change: Handbook Bonn, Germany: Climate Change Secretariat

Wang. S.S, Q. Zhou, P. Zhou, and Q.W. Wang (2011). CO_2 emissions, energy consumption and economic growth in China: a panel data analysis. Energy policy, 39, 4870-4875

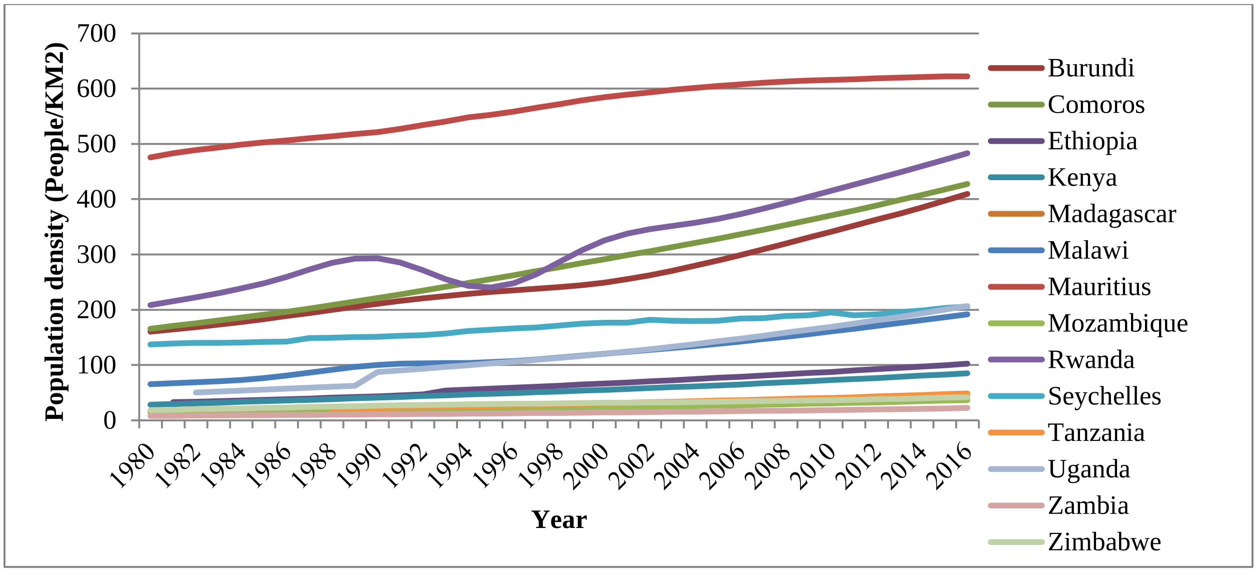
WB (2017). World Bank Group report. Reaping richer returns from public expenditure in agriculture. 9th Zambia economic brief.

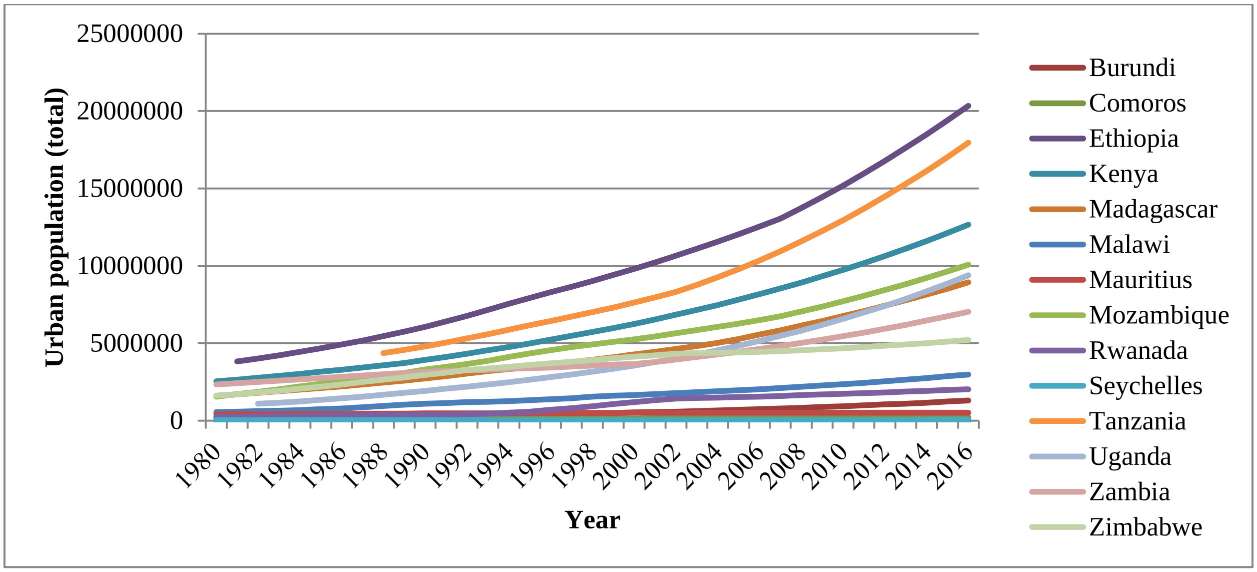
WB (2018). World Development Indicators database, World Bank. Washington, DC.

Zakarya, Y.G, Belmokaddem, M, Sahraou, M. A and Gueuil, M. S (2015). Factors affecting carbon dioxide emissions in the BRICS countries: A panel data analysis. Procedia economics and finance, 26, 114-125

APPENDICES

APPENDIX A: Figure 3.14: Historical trends of population density and urbanization by country





Source: World Bank

APPENDIX B: Descriptive statistics of the variables

Table 3.1: summary statistics result of the model variables by country

Country	Variable	observation	mean	Min	Max	Standard deviation
Burundi	CO_2	37	0.2385562	0.14656	0.50815	0.078861
	TPEC	37	0.0047692	0.0011472	0.0070273	0.0016103
	RGDPPC	37	264.3618	218.2835	337.7084	42.26593
	PD	37	259.3264	160.3122	409.8176	71.44259
	UR	37	574960.6	178629	1303728	322804.9
Comoros	CO_2	37	0.0963858	0.043968	0.18137	0.044095
	TPEC	37	0.0017994	0.0007091	0.0028788	0.0005532
	RGDPPC	37	820.4044	746.0924	938.1589	59.73608
	PD	37	282.6919	165.4105	427.5126	78.79155
	UR	37	145378.6	71463	227693	44894.61
Ethiopia	CO_2	36	4.636117	1.4739	12.9419	3.047888
	TPEC	36	0.0913326	0.0302474	0.2675155	0.0657238
	RGDPPC	36	254.7174	163.6233	511.1874	93.69042
	PD	36	64.0918	32.8068	102.4032	21.7027
	UR	36	10076005.69	3832363	20343419	4809385
Kenya	CO_2	37	8.24627	3.716	15.2342	3.23648
	TPEC	37	0.161043	0.0974625	0.3159412	0.059406
	RGDPPC	37	907.3564	823.0748	1143.364	80.56811
	PD	37	53.85196	28.58522	85.14876	16.7965
	UR	37	6358558	2535197	12700000	3016327
Madagascar	CO_2	37	1.629268	0.6504	3.0895	0.6625456
	TPEC	37	0.0286787	0.0150877	0.0580348	0.011897
	RGDPPC	37	447.1864	374.4891	621.7155	50.24364
	PD	37	26.71585	14.98874	42.78885	8.449783
	UR	37	4376897	1614654	8926190	2132053
Malawi	CO_2	37	0.85791	0.5372	1.3155	0.2197378
	TPEC	37	0.0204254	0.0112544	0.0316525	0.0062251
	RGDPPC	37	390.0117	315.9296	484.3686	48.29703
	PD	37	120.2081	65.36996	191.892	36.52349
	UR	37	1586729	557759	2986195	712648.8
Mauritius	CO_2	37	2.342016	0.50197	4.2246	1.294722
	TPEC	37	0.0443276	0.0116167	0.0858977	0.0236282
	RGDPPC	37	5362.416	2264.914	9822.008	2273.996
	PD	37	563.3932	475.8813	622.4005	48.85004

	UR	37	484434.6	409127	519756	37545.58
Mozambique	CO_2	37	2.318391	0.97673	9.8064	2.163718
	TPEC	37	0.1073997	0.0153946	0.309788	0.0887415
	RGDPPC	37	275.8407	131.6464	514.9615	123.0674
	PD	37	23.14328	15.06693	36.661	6.66915
	UR	37	5112360	1559003	10068983	2427007
Rwanda	CO_2	37	0.5904654	0.461	0.98418	0.1261572
	TPEC	37	0.0106407	0.0033168	0.0166391	0.0027413
	RGDPPC	37	434.9577	204.7317	738.8302	124.3138
	PD	37	322.9117	208.3792	483.0769	80.80185
	UR	37	1011249	242693	2032650	641672.9
Seychelles	CO_2	37	0.3668368	0.084272	0.73646	0.2139289
	TPEC	37	0.00974	0.002	0.0167363	0.0046319
	RGDPPC	37	8918.39	5368.842	13598.34	2355.4
	PD	37	169.008	137.5239	205.8196	20.88392
	UR	37	39831.41	31229	52859	6466.529
Tanzania	CO_2	29	5.122059	2.1616	13.6047	3.393348
	TPEC	29	0.0942416	0.0480499	0.2335178	0.0519686
	RGDPPC	29	588.6129	456.8931	867.0587	130.679
	PD	29	33.32549	21.09185	48.84866	8.337511
	UR	29	9436388	4356633	18000000	4056875
Uganda	CO_2	35	1.95309	0.5453	5.5714	1.542373
	TPEC	35	0.0389545	0.012653	0.0948501	0.0240492
	RGDPPC	35	432.9377	272.7497	662.4344	132.6625
	PD	35	119.7219	50.42248	206.9019	47.36767
	UR	35	4009097	1085452	9386237	2440055
Zambia	CO_2	37	2.68533	1.7782	4.5751	0.7426214
	TPEC	37	0.1233044	0.0964743	0.1776654	0.0208832
	RGDPPC	37	1170.65	903.9815	1629.59	230.7249
	PD	37	13.98845	7.922127	22.31855	4.199646
	UR	37	4009789	2344797	7041054	1307605
Zimbabwe	CO_2	37	12.06628	5.5195	17.6845	3.128625
	TPEC	37	0.1749027	0.1345883	0.2133858	0.021801
	RGDPPC	37	1079	593.1272	1347.972	218.5178
	PD	37	30.16758	18.51925	41.74838	6.341023
	UR	37	3655295	1602697	5215921	1085625

Source: own computations using STATA 13.0

Table 3.2: summary statistics result of the model variables by a panel

Variables	Obs	Natural logarithm	Mean	min	max	Standard deviation
CO2	507	without	3.051269	0.043968	17.6845	3.822127
		with	0.2968508	-3.124293	2.872689	1.420629

TPEC	507	without	0.06647032	0.0007091	0.3159412	0.0690706
		with	-3.513947	-7.251551	-1.152199	1.438612
RGDPPC	507	without	1546.363	131.6464	13598	2584.776
		With	6.588679	4.880119	9.517703	1.070744
PD	507	without	150.8561	7.922127	622.4005	159.5452
		with	4.413939	2.06966	6.433584	1.150911
UR	507	Actual	3528329	31229	2.03e+07	3777127
		Growth	4.162764	-1.912491	17.62512	2.256448

Source: own computation using STATA 13.0

Where CO_2 is carbon dioxide emission (in $MTCO_2$), TPEC is total primary energy consumption (in quadrillion Btu), RGDPPC is gross domestic product per capita (in constant 2010 $US), PD is population density (in people in sq.km of land area) and UR is urban population (total).

APPENDIX C: A complete derivation of the re-parameterized of ARDL error-correction model for time series

To develop the re-parameterized time series ARDL error-correction model, let's consider the time series version of the ARDL (1, 1) model.

$y_t = \delta_0 + \delta_1 x_t + \delta_2 x_{t-1} + \lambda y_{t-1} + e_t$ …………………………………………………......Equ(1)

When y_{t-1} is subtracted from both sides of the model, we have the following

$\Delta y_t = \delta_0 + \delta_1 x_t + \delta_2 x_{t-1} + (\lambda - 1) y_{t-1} + e_t$……………………………………………Equ(2)

Now let's assume $\Phi = (1 - \lambda)$ meaning $(\lambda - 1) = -\Phi$

By substituting $-\Phi$ for $(\lambda - 1)$, we have

$\Delta y_t = \delta_0 + \delta_1 x_t + \delta_2 x_{t-1} - \Phi y_{t-1} + e_t$…………………………………………………Equ(3)

It is well known that $\Delta x_t = x_t - x_{t-1}$ and $x_t = \Delta x_t + x_{t-1}$. Now substituting $\Delta x_t + x_{t-1}$ for x_t gives

$\Delta y_t = \delta_0 + \delta_1 (\Delta x_t + x_{t-1}) + \delta_2 x_{t-1} - \Phi y_{t-1} + e_t$

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t + \delta_1 x_{t-1} + \delta_2 x_{t-1} - \Phi y_{t-1} + e_t$

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t + (\delta_1 + \delta_2) x_{t-1} - \Phi y_{t-1} + e_t$…………………………………….……Equ(4)

Assuming $(\delta_1 + \delta_2) = \mu$, we have the following

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t + \mu x_{t-1} - \Phi y_{t-1} + e_t$

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t + (\mu x_{t-1} - \Phi y_{t-1}) + e_t$……………………………………………..Equ (5)

Multiplying the terms in the bracket $\frac{\Phi}{\Phi}$ will give us

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t + \Phi(\frac{\mu}{\Phi} x_{t-1} - y_{t-1}) + e_t$

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t - \Phi(y_{t-1} - (\frac{\mu}{\Phi}) x_{t-1}) + e_t$ ………………………………………....Equ (6)

As it can be seen above $\Phi = (1 - \lambda)$, $\mu = (\delta_1 + \delta_2)$, by substituting these in to equation we have

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t - (1 - \lambda)(y_{t-1} - (\frac{\delta_1 + \delta_2}{(1-\lambda)}) x_{t-1}) + e_t$ ……………………………….Equ (7)

Taking $-(\frac{\mu}{\Phi})$ or $-(\frac{\delta_1 + \delta_2}{(1-\lambda)}) = \Omega$, we have

$\Delta y_t = \delta_0 + \delta_1 \Delta x_t - (1 - \lambda)(y_{t-1} - \Omega x_{t-1}) + e_t$ ………………………………………Equ (8)

Therefore, $(y_{t-1} - \Omega x_{t-1})$ is the error correcting term lagged by one period or ECM_{t-1} and $-(1 - \lambda)$ is the error correcting parameter which measures the speed of adjustment of the model.

Assuming the maximum lags for the variable to be one, a reasonable generalization of the above error correction model for more than one explanatory variable is as follows

$\Delta y_t = \delta_0 + \delta_1 \Delta x_{1t} + \delta_2 \Delta x_{2t} + \delta_3 \Delta x_{3t} + \cdots .. + \delta_k \Delta x_{kt} - (1 - \lambda)(y_{t-1} - \Omega_1 x_{1t-1} - \Omega_2 x_{2t-1} - \Omega_3 x_{3t-1} - \cdots - \Omega_k x_{kt-1}) + e_t$ ………………………………………………Equ (9)

Where, $\delta_1, \delta_2, \delta_3, , , , \delta_k$ are coefficients that measure the short –run relationship

$\Omega_1, \Omega_2, \Omega_3, , , , \Omega_k$ are coefficients that measure the long-run relationship

From equation (9), one can generalize for the panel data too as

$\Delta y_{i,t} = \delta_{i,0} + \delta_{i,1} \Delta x_{i,t} + \delta_{i,2} \Delta x_{2i,t} + \delta_{i,3} \Delta x_{3i,t} + \cdots .. + \delta_{i,k} \Delta x_{ki,t} - (1 - \lambda)(y_{i,t-1} - \Omega_{1i} x_{1i,t-1} - \Omega_{2i} x_{2i,t-1} - \Omega_{3i} x_{3i,t-1} - \cdots - \Omega_{ki} x_{ki,t-1}) + e_{i,t}$ ………………………Equ (10)

APPENDIX D: A complete derivation of the re-parameterized panel-ARDL error correction model

To develop re-parameterized panel ARDL (p, q, q, q, q) error correction model taking the variables under analysis, let's consider the co-integration regression equation that specified as an autoregressive distributive lag (ARDL) (1, 1, 1, 1, 1) model:

$LCO_{2i,t}$=$\rho_i LCO_{2i,t-1}$+ $\beta_{10i}LTPEC_{i,t}$+ $\beta_{11i}LTPEC_{i,t-1}$+ $\beta_{20i}LRGDPPC_{i,t}$ + $\beta_{21i}LRGDPPC_{i,t-1}$ + $\beta_{30i}LPD_{i,t}$ + $\beta_{31i}LPD_{i,t-1}$ + $\beta_{40i}UR_{i,t}$ + $\beta_{41i}UR_{i,t-1}$ + μ_i + $e_{i,t}$………………..Equ (1)

Subtracting $LCO_{2i,t-1}$ from both sides of the model will give us the following equation:

$\Delta LCO_{2i,t}$=($\rho_i - 1$)$LCO_{2i,t-1}$+ $\beta_{10i}LTPEC_{i,t}$+ $\beta_{11i}LTPEC_{i,t-1}$+ $\beta_{20i}LRGDPPC_{i,t}$ + $\beta_{21i}LRGDPPC_{i,t-1}$ + $\beta_{30i}LPD_{i,t}$ + $\beta_{31i}LPD_{i,t-1}$ + $\beta_{40i}UR_{i,t}$ + $\beta_{41i}UR_{i,t-1}$ + μ_i + $e_{i,t}$…………………………………………………………………………………Equ (2)

Let assume (1-ρ_i) = φ_i, then ($\rho_i - 1$) = -φ_i. Therefore, by substituting -φ_i in to the equation (2) above will give us the following equation:

$\Delta LCO_{2i,t}$ = $\beta_{10i}LTPEC_{i,t}$+ $\beta_{11i}LTPEC_{i,t-1}$+ $\beta_{20i}LRGDPPC_{i,t}$ + $\beta_{21i}LRGDPPC_{i,t-1}$ + $\beta_{30i}LPD_{i,t}$ + $\beta_{31i}LPD_{i,t-1}$ + $\beta_{40i}UR_{i,t}$ + $\beta_{41i}UR_{i,t-1}$ -$\varphi_i LCO_{2i,t-1}$ + μ_i + $e_{i,t}$ ……………………………………………………………………………………….Equ (3)

It is well known that:

- $\Delta LTPEC_{i,t}$ = $LTPEC_{i,t}$ - $LTPEC_{i,t-1}$. From this, $LTPEC_{i,t}$ = $\Delta LTPEC_{i,t} + LTPEC_{i,t-1}$
- $\Delta LRGDPPC_{i,t}$ = $LRGDPPC_{i,t}$ - $LRGDPPC_{i,t-1}$. From this, $LRGDPPC_{i,t}$ = $\Delta LRGDPPC_{i,t} + LRGDPPC_{i,t-1}$
- $\Delta LPD_{i,t}$ = $LPD_{i,t}$ - $LPD_{i,t-1}$. From this, $LPD_{i,t}$ = $\Delta LPD_{i,t} + LPD_{i,t-1}$
- $\Delta UR_{i,t}$ = $UR_{i,t}$ – $UR_{i,t-1}$. From this, $UR_{i,t}$ = $\Delta UR_{i,t} + UR_{i,t-1}$

Now substituting $LTPEC_{i,t}$, $LRGDPPC_{i,t}$, $LPD_{i,t}$ *and* $UR_{i,t}$ in the above equation or in equation (3) will give us:

$\Delta LCO_{2i,t} = \beta_{10i}(\Delta LTPEC_{i,t} + LTPEC_{i,t-1}) + \beta_{11i}LTPEC_{i,t-1} + \beta_{20i}(\Delta LRGDPPC_{i,t} + LRGDPPC_{i,t-1}) + \beta_{21i}LRGDPPC_{i,t-1} + \beta_{30i}(\Delta LPD_{i,t} + LPD_{i,t-1}) + \beta_{31i}LPD_{i,t-1} + \beta_{40i}(\Delta UR_{i,t} + UR_{i,t-1}) + \beta_{41i}UR_{i,t-1} - \varphi_i LCO_{2i,t-1} + \mu_i + e_{i,t}$

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{10i}LTPEC_{i,t-1} + \beta_{11i}LTPEC_{i,t-1} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{20i}LRGDPPC_{i,t-1} + \beta_{21i}LRGDPPC_{i,t-1} + \beta_{30i}\Delta LPD_{i,t} + \beta_{30i}LPD_{i,t-1} + \beta_{31i}LPD_{i,t-1} + \beta_{40i}\Delta UR_{i,t} + \beta_{40i}UR_{i,t-1} + \beta_{41i}UR_{i,t-1} - \varphi_i LCO_{2i,t-1} + \mu_i + e_{i,t}$

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + (\beta_{10i} + \beta_{11i})LTPEC_{i,t-1} + \beta_{20i}\Delta LRGDPPC_{i,t} + (\beta_{20i} + \beta_{21i})LRGDPPC_{i,t-1} + \beta_{30i}\Delta LPD_{i,t} + (\beta_{30i} + \beta_{31i})LPD_{i,t-1} + \beta_{40i}\Delta UR_{i,t} + (\beta_{40i} + \beta_{41i})UR_{i,t-1} - \varphi_i LCO_{2i,t-1} + \mu_i + e_{i,t}$ ……………………………………………Equ(4)

Now let us assume $(\beta_{10i} + \beta_{11i}) = \psi$, $(\beta_{20i} + \beta_{21i}) = \Omega$, $(\beta_{30i} + \beta_{31i}) = \Phi$, $(\beta_{40i} + \beta_{41i}) = \eta$, then equation (4) becomes:

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \psi LTPEC_{i,t-1} + \beta_{20i}\Delta LRGDPPC_{i,t} + \Omega LRGDPPC_{i,t-1} + \beta_{30i}\Delta LPD_{i,t} + \Phi LPD_{i,t-1} + \beta_{40i}\Delta UR_{i,t} + \eta UR_{i,t-1} - \varphi_i LCO_{2i,t-1} + \mu_i + e_{i,t}$

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{30i}\Delta LPD_{i,t} + \beta_{40i}\Delta UR_{i,t} + (\psi LTPEC_{i,t-1} + \Omega LRGDPPC_{i,t-1} + \Phi LPD_{i,t-1} + \eta UR_{i,t-1} - \varphi_i LCO_{2i,t-1} + \mu_i) + e_{i,t}$……………………Equ(5)

Now let us multiply the term in the bracket or $(\psi LTPEC_{i,t-1} + \Omega LRGDPPC_{i,t-1} + \Phi LPD_{i,t-1} + \eta UR_{i,t-1} - \varphi_i LCO_{2i,t-1} + \mu_i)$ by $\frac{\varphi_i}{\varphi_i}$ and this will give the following:

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{30i}\Delta LPD_{i,t} + \beta_{40i}\Delta LUR_{i,t} - \varphi_i(LCO_{2i,t-1} - \frac{\psi}{\varphi_i}LTPEC_{i,t-1} - \frac{\Omega}{\varphi_i}LRGDPPC_{i,t-1} - \frac{\Phi}{\varphi_i}LPD_{i,t-1} - \frac{\eta}{\varphi_i}UR_{i,t-1} - \frac{\mu_i}{\varphi_i}) + e_{i,t}$ ……………..Equ(6)

Then we can write the panel error correction model as follows:

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{30i}\Delta LPD_{i,t} + \beta_{40i}\Delta UR_{i,t} - \varphi_i(LCO_{2i,t-1} - \theta_{1i}LTPEC_{i,t-1} - \theta_{2i}LRGDPPC_{i,t-1} - \theta_{3i}LPD_{i,t-1} - \theta_{4i}UR_{i,t-1} - \theta_{0i}) + e_{i,t}$ ………..Equ(7)

Where, $\theta_{0i} = \frac{\mu_i}{\varphi_i}, \theta_{1i} = -\left(\frac{\Psi}{\varphi_i}\right), \theta_{2i} = -\left(\frac{\Omega}{\varphi_i}\right), \theta_{3i} = -(\frac{\Phi}{\varphi_i}), \theta_{4i} = -(\frac{\eta}{\varphi_i}), (\beta_{10i} + \beta_{11i}) = \psi,$ $(\beta_{20i} + \beta_{21i}) = \Omega, (\beta_{30i} + \beta_{31i}) = \Phi, (\beta_{40i} + \beta_{41i}) = \eta, \varphi_i = (1 - \rho_i)$

Then, equation (7) can also rewrite as:

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{30i}\Delta LPD_{i,t} + \beta_{40i}\Delta UR_{i,t} - (1 - \rho_i)(LCO_{2i,t-1} - (\frac{\beta_{10i} + \beta_{11i}}{(1-\rho_i)})LTPEC_{i,t-1} - (\frac{\beta_{20i} + \beta_{21i}}{(1-\rho_i)})LRGDPPC_{i,t-1} - (\frac{\beta_{30i} + \beta_{31i}}{(1-\rho_i)})LPD_{i,t-1} - (\frac{\beta_{40i} + \beta_{41i}}{(1-\rho_i)})UR_{i,t-1} - \theta_{0i}) + e_{i,t}$ ……………………………………………………Equ(8)

Let's take again $-(1 - \rho_i) = \varphi_i$, and equation (8) becomes:

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{30i}\Delta LPD_{i,t} + \beta_{40i}\Delta UR_{i,t} + \varphi_i[LCO_{2i,t-1} - (\frac{\beta_{10i} + \beta_{11i}}{(1-\rho_i)})LTPEC_{i,t-1} - (\frac{\beta_{20i} + \beta_{21i}}{(1-\rho_i)})LRGDPPC_{i,t-1} - \left(\frac{\beta_{30i} + \beta_{31i}}{(1-\rho_i)}\right)LPD_{i,t-1} - (\frac{\beta_{40i} + \beta_{41i}}{(1-\rho_i)})UR_{i,t-1} - \theta_{0i}] + e_{i,t}$ ………………………………………………………..……………Equ(9)

The terms in the square bracket in equation (9) represents the error correction term lagged by one period or the lagged value of the residual extracted from the long-term co-integration regression equation. This is commonly represented by the symbol $ECT_{i,t-1}$.

Equation (9) can also rewrite as:

$\Delta LCO_{2i,t} = \beta_{10i}\Delta LTPEC_{i,t} + \beta_{20i}\Delta LRGDPPC_{i,t} + \beta_{30i}\Delta LPD_{i,t} + \beta_{40i}\Delta UR_{i,t} + \varphi_i\ ECT_{i,t-1} + e_{i,t}$ ………………………………………………………………Equ(10)

Given this, now the general Panel ARDL (p, q, q, q, q) model in equation (1) can be expressed in the re-parameterized error correction model as follows:

$\Delta LCO_{2i,t} = \sum_{j=1}^{p-1} \gamma_{i,j}\, \Delta LCO_{2i,t-j} + \sum_{j=0}^{q-1} \lambda_{i,j}\, \Delta LTPEC_{i,t-j} + \sum_{j=0}^{q-1} \delta_{i,j}\, \Delta LRGDPPC_{i,t-j} + \sum_{j=0}^{q-1} \theta_{i,j}\, \Delta LPD_{i,t-j} + \sum_{j=0}^{q-1} \sigma_{i,j}\, \Delta UR_{i,t-j} + \varphi_i\ ECT_{i,t-1} + e_{i,t}$ …………………………..Equ (11)

Where, $ECM_{i,t-1} = LCO_{2i,t-1} - (\frac{\beta_{10i} + \beta_{11i}}{(1-\rho)})LTPEC_{i,t-1}$ – $(\frac{\beta_{20i} + \beta_{21i}}{(1-\rho)})LRGDPPC_{i,t-1}$ - $(\frac{\beta_{30i} + \beta_{31i}}{(1-\rho)})LPD_{i,t-1}$ - $(\frac{\beta_{40i} + \beta_{41i}}{(1-\rho)})UR_{i,t-1}$ - θ_{0i}, all other things are as they are defined earlier.

Therefore, the following Panel ARDL equation is the final equation to check for the long-run co-integration relationships between the variables of interest such as carbon dioxide emissions, total primary energy consumption, real gross domestic product per capita, population density and urbanization:

$$\Delta LCO_{2i,t} = \sum_{j=1}^{p-1} \gamma_{i,j}\, \Delta LCO_{2i,t-j} + \sum_{j=0}^{q-1} \lambda_{i,j}\, \Delta LTPEC_{i,t-j} + \sum_{j=0}^{q-1} \delta_{i,j}\, \Delta LRGDPPC_{i,t-j} + \sum_{j=0}^{q-1} \alpha_{i,j}\, \Delta LPD_{i,t-j} + \sum_{j=0}^{q-1} \sigma_{i,j} \Delta\, UR_{i,t-j} + \varphi_i [LCO_{2i,t-1} - \theta_{1i} LTPEC_{i,t-1} - \theta_{2i} LRGDPPC_{i,t-1} - \theta_{3i} LPD_{i,t-1} - \theta_{4i} UR_{i,t-1} - \theta_{0i}] + e_{i,t} \quad \text{Equ (12)}$$

APPENDIX E: Multi-co-linearity test result

Table 5.1 Country-specific correlation matrix and VIF statistics for the explanatory variables

Country	Correlation and VIF statistics					
Burundi	Correlation		LTPEC	LRGDPPC	LPD	URG
		LTPEC	1			
		LRGDPPC	-0.3337	1		
		LPD	0.5874	-0.7532	1	
		URG	-0.6349	0.3599	-0.2152	1
	Collin	VIF	3.75	3.68	5.11	2.73
		Mean VIF=3.81				
	VIF	VIF	3.75	3.68	5.11	2.73
		1/VIF	0.266642	0.272064	0.195848	0.366752
		Mean VIF=3.81				
Comoros	Correlation	LTPEC	1			
		LRGDPPC	-0.5752	1		
		LPD	0.7729	-0.8073	1	
		URG	-0.5555	0.8374	-0.8179	1
	Collin	VIF	2.60	3.95	6.03	4.27
		Mean VIF=4.21				
	VIF	VIF	2.60	3.95	6.03	4.27
		1/VIF	0.384624	0.253337	0.165967	0.234167
		Mean VIF=4.21				
Ethiopia	Correlation	LTPEC	1			
		LRGDPPC	0.8718	1		
		LPD	0.8913	0.6656	1	
		URG	-0.0857	0.0196	-0.3409	1
	Collin	VIF	18.29	5.69	9.72	1.56
		Mean VIF=8.82				
	VIF	VIF	18.29	5.69	9.72	1.56

		1/VIF	0.054666	0.175809	0.102897	0.639026
		Mean VIF=8.82				
Kenya	Correlation	LTPEC	1			
		LRGDPPC	0.7279	1		
		LPD	0.9642	0.5688	1	
		URG	-0.2566	-0.2417	-0.2207	1
	Collin	VIF	44.32	4.57	30.69	1.08
		Mean VIF=20.17				
	VIF	VIF	44.32	4.57	30.69	1.08
		1/VIF	0.022564	0.218760	0.032585	0.923931
		Mean VIF=20.17				
Madagascar	Correlation	LTPEC	1			
		LRGDPPC	-0.6205	1		
		LPD	0.9319	-0.8030	1	
		URG	-0.3976	0.7162	-0.4957	1
	Collin	VIF	12.46	7.11	22.23	2.27
		Mean VIF= 11.02				
	VIF	VIF	12.46	7.11	22.23	2.27
		1/VIF	0.080260	0.140651	0.044992	0.440020
		Mean VIF= 11.02				
Malawi	Correlation	LTPEC	1			
		LRGDPPC	0.5475	1		
		LPD	0.9442	0.6388	1	
		URG	-0.6720	-0.3220	-0.5528	1
	Collin	VIF	13.63	1.72	12.42	2.06
		Mean VIF=7.46				
	VIF	VIF	13.63	1.72	12.42	2.06
		1/VIF	0.073379	0.581864	0.080534	0.484471
		Mean VIF=7.46				
Mauritius	Correlation	LTPEC	1			
		LRGDPPC	0.9830	1		
		LPD	0.9859	0.9840	1	
		URG	-0.8040	-0.8400	-0.8254	1
	Collin	VIF	46.96	44.46	47.63	3.63
		Mean VIF=35.67				
	VIF	VIF	46.96	44.46	47.63	3.63
		1/VIF	0.021294	0.022494	0.020994	0.275152
		Mean VIF=35.67				
Mozambique	Correlation	LTPEC	1			
		LRGDPPC	0.8801	1		
		LPD	0.8027	0.9671	1	
		URG	-0.4705	-0.6731	-0.7089	1
	Collin	VIF	5.66	29.60	19.19	2.16
		Mean VIF=14.15				
	VIF	VIF	5.66	29.60	19.19	2.16
		1/VIF	0.176583	0.033789	0.052123	0.462508
		Mean VIF=14.15				
Rwanda	Correlation	LTPEC	1			
		LRGDPPC	0.2105	1		
		LPD	0.4436	0.7278	1	
		URG	0.0686	-0.6391	-0.4482	1
	Collin	VIF	1.40	2.88	2.64	1.84

		Mean VIF=2.19				
	VIF	VIF	1.40	2.88	2.64	1.84
		1/VIF	0.713591	0.347712	0.378412	0.543164
		Mean VIF=2.19				
Seychelles	Correlation	LTPEC	1			
		LRGDPPC	0.8952	1		
		LPD	0.9310	0.9681	1	
		URG	0.2215	0.2974	0.3121	1
	Collin	VIF	7.86	16.10	24.96	1.15
		Mean VIF=12.52				
	VIF	VIF	7.86	16.10	24.96	1.15
		1/VIF	0.127266	0.062097	0.040070	0.865870
		Mean VIF=12.52				
Tanzania	Correlation	LTPEC	1			
		LRGDPPC	0.9927	1		
		LPD	0.9527	0.9340	1	
		URG	0.6102	0.6492	0.4580	1
	Collin	VIF	105.96	87.29	14.88	2.47
		Mean VIF=52.65				
	VIF	VIF	105.96	87.29	14.88	2.47
		1/VIF	0.009437	0.011456	0.067187	0.404059
		Mean VIF=52.65				
Uganda	Correlation	LTPEC	1			
		LRGDPPC	0.9775	1		
		LPD	0.9751	0.9431	1	
		URG	-0.7677	-0.7566	-0.8465	1
	Collin	VIF	70.68	25.40	43.62	5.01
		Mean VIF=36.18				
	VIF	VIF	70.68	25.40	43.62	5.01
		1/VIF	0.014149	0.039376	0.022924	0.199800
		Mean VIF=36.18				
Zambia	Correlation	LTPEC	1			
		LRGDPPC	0.9303	1		
		LPD	0.3587	0.4914	1	
		URG	0.6956	0.7535	0.3626	1
	Collin	VIF	8.22	10.95	1.46	2.32
		Mean VIF=5.74				
	VIF	VIF	8.22	10.95	1.46	2.32
		1/VIF	0.121678	0.091284	0.686168	0.431833
		Mean VIF=5.74				
Zimbabwe	Correlation	LTPEC	1			
		LRGDPPC	0.2939	1		
		LPD	0.3914	-0.6083	1	
		URG	-0.2255	0.6718	-0.8916	1
	Collin	VIF	2.52	3.55	7.24	5.62
		Mean VIF=4.73				
	VIF	VIF	2.52	3.55	7.24	5.62
		1/VIF	0.396394	0.281356	0.138183	0.177918
		Mean VIF=4.73				

Note: The variance inflation factor statistics for the explanatory variables are obtained by utilizing the COLLIN and VIF command in STATA 13.0 package. These two commands provide the same variance inflation factor statistics but the former can be used both before and after estimation of the model whereas the later can be used only after the regression and it requires the last regression command must be reg (or regress).

Table 5.2 Panel-level correlation matrix and VIF statistics

Correlation		LTPEC	LRGDPPC	LPD	URG
	LTPEC	1			
	LRGDPPC	0.0309	1		
	LPD	-0.5829	0.2885	1	
	URG	-0.0314	-0.6398	-0.2071	1
Collin	VIF	1.62	1.83	1.77	1.70
	Mean VIF= 1.73				

Note: The value of VIF for the explanatory/independent variable in the panel data is obtained using COLLIN command in STATA 13.0 package because VIF command needs reg/regress option before it. Actually, both commands provide the same result.

APPENDIX F: Model diagnostic tests results by country

Table 5.9 diagnostic tests for the selected model in country level

Diagnostic tests

Model: ARDL (1, 1, 1, 1, 1)

Country	Serial correlation(Berusch pagan –lm test)	Heteroskedasticity (Berusch pagan test)	Function form(Ramsey rest-test)	Normality(JB-test)
Burundi	F-s =18.15222 P-v=0.0003***	F-s =0.488110 P-v=0.8692	F-s =3.443276 P-v=0.0753	F-s =0.254407 P-v=0.880555
Comoros	F-s =1.101750 P-v=0.3039	F-s =1.192325 P-v=0.3408	F-s =4.671886 P-v=0.0404**	F-s =0.743252 P-v=0.689612
Ethiopia	F-s =1.152344 P-v=0.2937	F-s =2.036528 P-v=0.0775	F-s =0.302108 P-v=0.5876	F-s =5.000302 P-v=0.082073
Kenya	F-s =0.344305 P-v=0.5626	F-s =0.818542 P-v=0.6045	F-s =0.144465 P-v=0.7071	F-s =0.499743 P-v=0.778901
Madagascar	F-s =0.045530 P-v=0.8328	F-s =0.559185 P-v=0.8173	F-s =1.987021 P-v=0.1710	F-s =29.183448 P-v=0.0000***
Malawi	F-s =7.833706 P-v=0.0097***	F-s =1.725654 P-v=0.1334	F-s =1221190 P-v=0.2796	F-s =0.443906 P-v=0.800953
Mauritius	F-s =0.500375 P-v=0.4859	F-s =2.445224 P-v=00362**	F-s =9.604633 P-v=0.0048***	F-s =0.339207 P-v=0.843999
Mozambique	F-s =0.085137 P-v=0.7729	F-s =0.493032 P-v=0.8658	F-s =3.020188 P-v=0.0945	F-s =146.7922 P-v=0.0000***
Rwanda	F-s =0.327087 P-v=0.5725	F-s =1.076718 P-v=0.4117	F-s =1.356067 P-v=0.2552	F-s =2.299456 P-v=0.3167211
Seychelles	F-s =0.181174 P-v=0.6740	F-s =0.420586 P-v=0.9121	F-s =0.309075 P-v=0.5832	F-s =7.109379 P-v=0.028590**
Tanzania	F-s =0.085069 P-v=0.7741	F-s =0.385618 P-v=0.9268	F-s =2.794325 P-v=0.1135	F-s =53.09637 P-v=0.0000***
Uganda	F-s =0.005865 P-v=0.9396	F-s =0.874300 P-v=0.5604	F-s =2.575825 P-v=0.1222	F-s =0.150385 P-v=0.927565
Zambia	F-s =0.393399 P-v=0.5362	F-s =0.4077603 P-v=0.8763	F-s =1.176955 P-v=0.2883	F-s =0.126442 P-v=0.938736

Zimbabwe	F-s =0.087115 P-v=0.7703	F-s =1.190546 P-v=0.3418	F-s =0.762447 P-v=0.3909	F-s =5.693490 P-v=0.058033

Note: *** and ** indicate the rejection of a null hypothesis of no co-integration at 1% and 5% level of significance.
Source: Own Estimation using Eviews 9.0

APPENDIX G: Individual country-specific short-run PMG estimation results

Table 5.10 country-specific short-run dynamic coefficients of the Panel-ARDL (1, 1, 1, 1, 1) model

Dependent variable: D (LCO_2)
Model: Panel-ARDL (1, 1, 1, 1, 1)
Estimator: Pooled Mean Group (PMG)

Country	Independent variables and their coefficients					
	D(LTPEC)	D(LRGDPP)	D(LPD)	D(UR)	ECT_{-1}	C
Burundi	0.105424 (0.001)***	0.318412 (0.4669)	1.80662 (0.91063)	-0.096359 (0.003)***	-0.000728 (0.9284)	-0.017032 (0.2170)
Comoros	0.240819 (0.000)***	-0.217528 (0.5908)	-17.6535 (0.93821)	-0.019249 (0.0293)**	-0.132646 (0.001)***	0.492263 (0.041)**
Ethiopia	0.258965 (0.002)***	0.367541 (0.0137)**	-0.11643 (0.8994)	-0.07336 (0.000)***	-0.121333 (0.000)***	0.027690 (0.000)***
Kenya	0.399968 (0.0465)**	0.019655 (0.9810)	-4.20700 (0.8771)	-0.084722 (0.003)***	-0.330249 (0.000)***	0.127395 (0.0133)**
Madagascar	0.056781 (0.1870)	1.118596 (0.0412)**	24.94692 (0.9439)	-0.133776 (0.000)***	-0.429174 (0.000)***	-0.712893 (0.0842)
Malawi	0.096670 (0.009)***	0.161492 (0.0504)*	-4.04896 (0.2262)	-0.023353 (0.000)***	-0.330337 (0.000)***	0.125120 (0.000)***
Mauritiuss	-0.320160 (0.001)***	-0.062468 (0.8539)	7.918394 (0.7777)	-0.059403 (0.000)***	-0.807547 (0.000)***	-0.031837 (0.001)***
Mozambique	0.099781 (0.008)***	0.528691 (0.027)**	2.21308 (0.7663)	-0.008094 (0.005)***	-0.091787 (0.000)***	-0.042653 (0.003)***
Rwanda	0.135085 (0.005)***	0.046052 (0.014)**	0.789169 (0.032)***	0.007852 (0.000)***	-0.001934 (0.0426)**	-0.0056761 (0.001)***
Seychelles	0.389374 (0.004)***	0.374307 (0.3049)	-0.769911 (0.9534)	0.023256 (0.000)***	-0.138349 (0.0012)***	0.024683 (0.0021)***
Tanzania	-0.037266 (0.7175)	0.374872 (0.7702)	-0.020359 (0.9998)	-0.037741 (0.0106)**	-0.376608 (0.0002)***	0.034369 (0.6620)
Uganda	0.179847 (0.009)***	0.559656 (0.1026)	-0.441788 (0.005)***	0.136895 (0.007)***	-0.126848 (0.0014)***	0.058834 (0.000)***
Zambia	0.986206 (0.001)***	-0.218778 (0.4115)	-0.288235 (0.9944)	-0.007022 (0.002)***	-0.125502 (0.0002)***	0.011204 (0.7445)
Zimbabwe	0.348767 (0.0935)*	-0.224441 (0.0759)*	-7.826606 (0.7061)	-0.024115 (0.003)***	-0.611491 (0.0001)***	0.175043 (0.0005)***

Note: ***, ** and * indicate the rejection of a null hypothesis of statistical insignificance of the coefficients at 1%, 5% and 10% level of significance.
Source: Own Estimation using Eviews 9.0